Defense Research and Engineering: *Technologies to Produce Joint Capabilities*

Dr. Ronald M. Sega
Director of Defense Research and Engineering

April 22, 2004

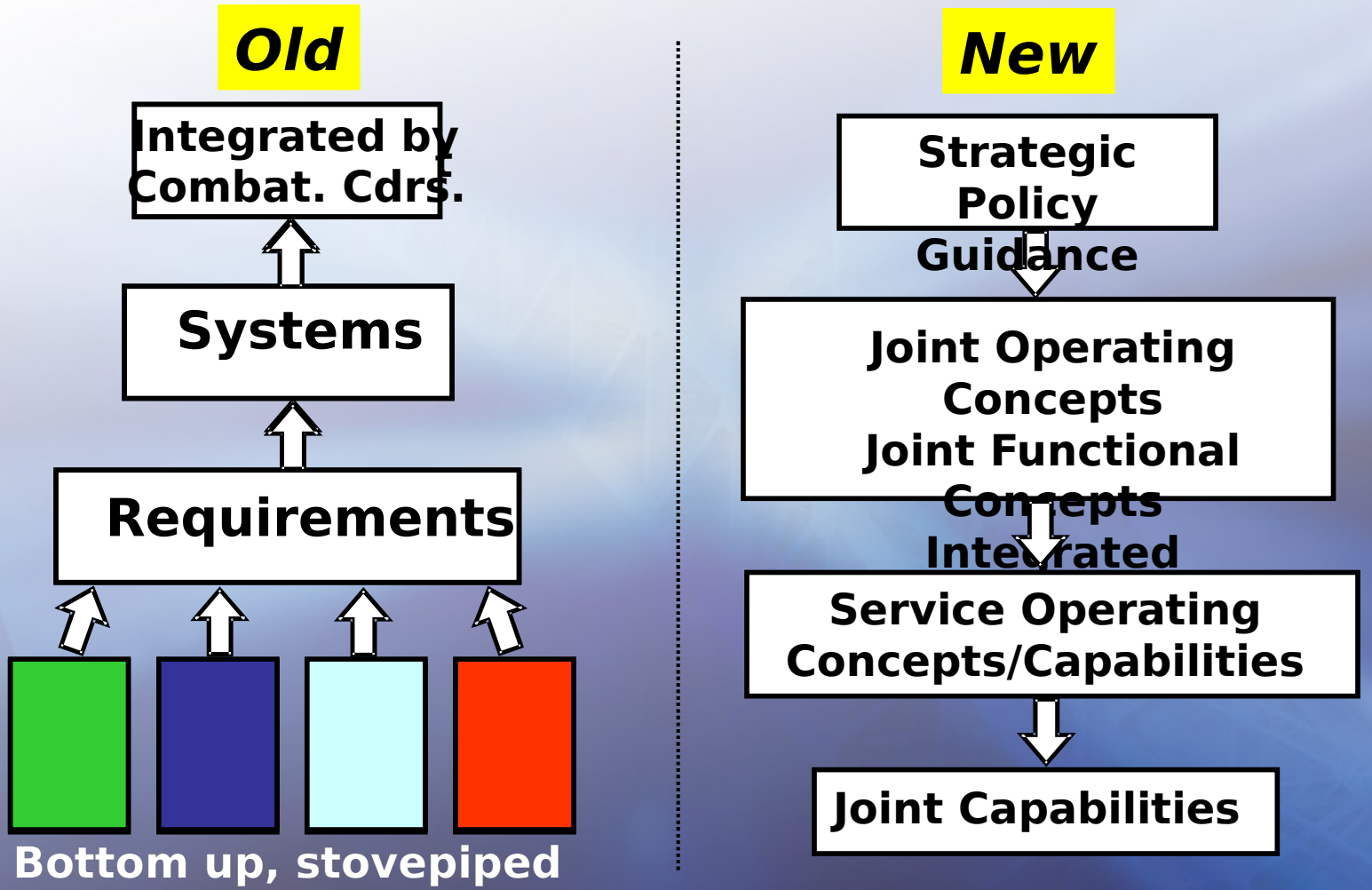
Distribution Statement A: Approved for public release: distribution unlimited

Agenda

- S&T Integrated Planning Process
- Transformational Initiatives
  - National Aerospace Initiative
  - Energy & Power Technologies
  - Surveillance & Knowledge Systems
- Combating Terrorism Technology Task Force (CTTTF)
- Science & Engineering Workforce: The Need for Innovation
- Summary

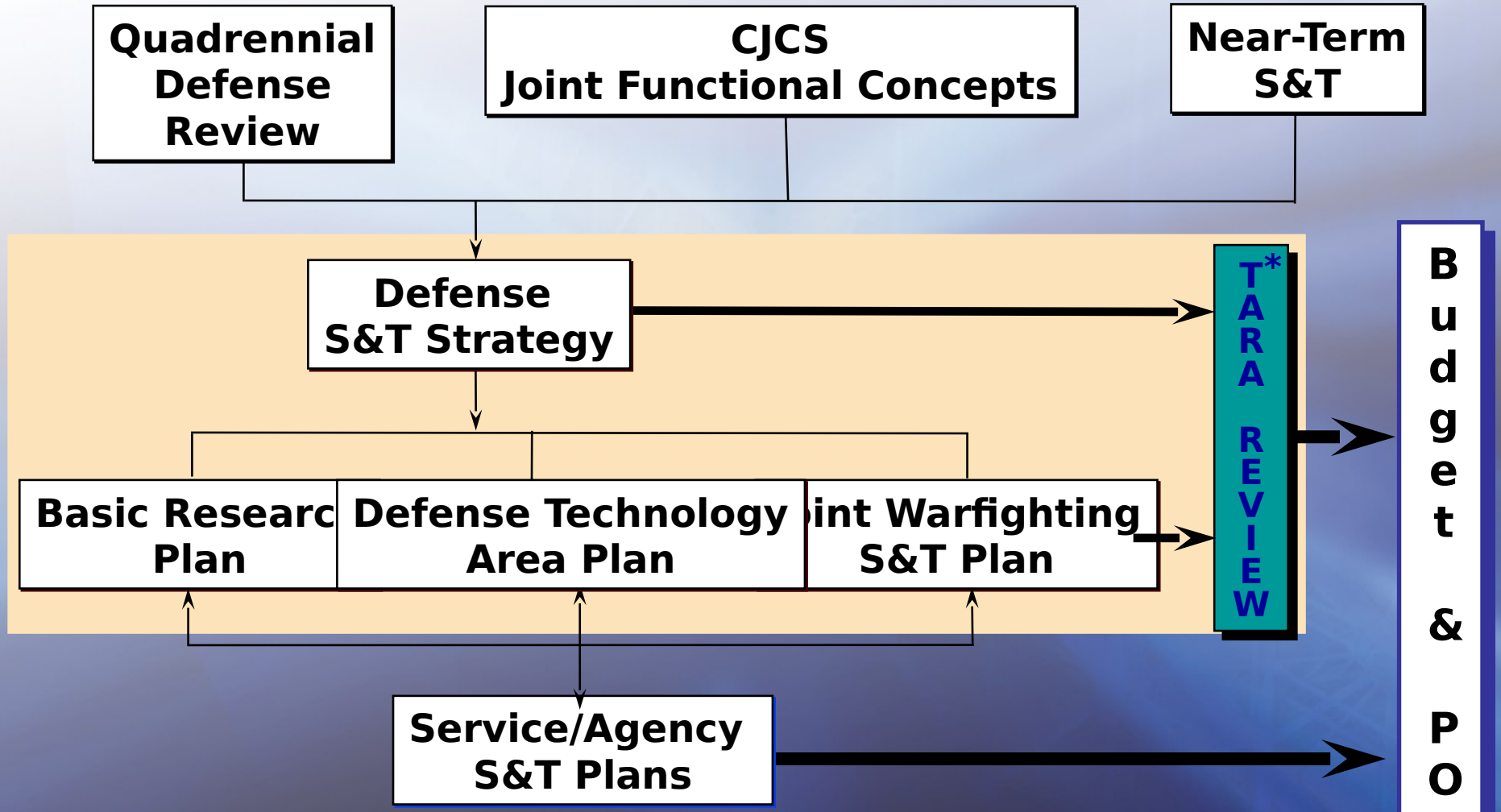
Distribution Statement A: Approved for public release: distribution unlimited

New Process



Distribution Sta limited

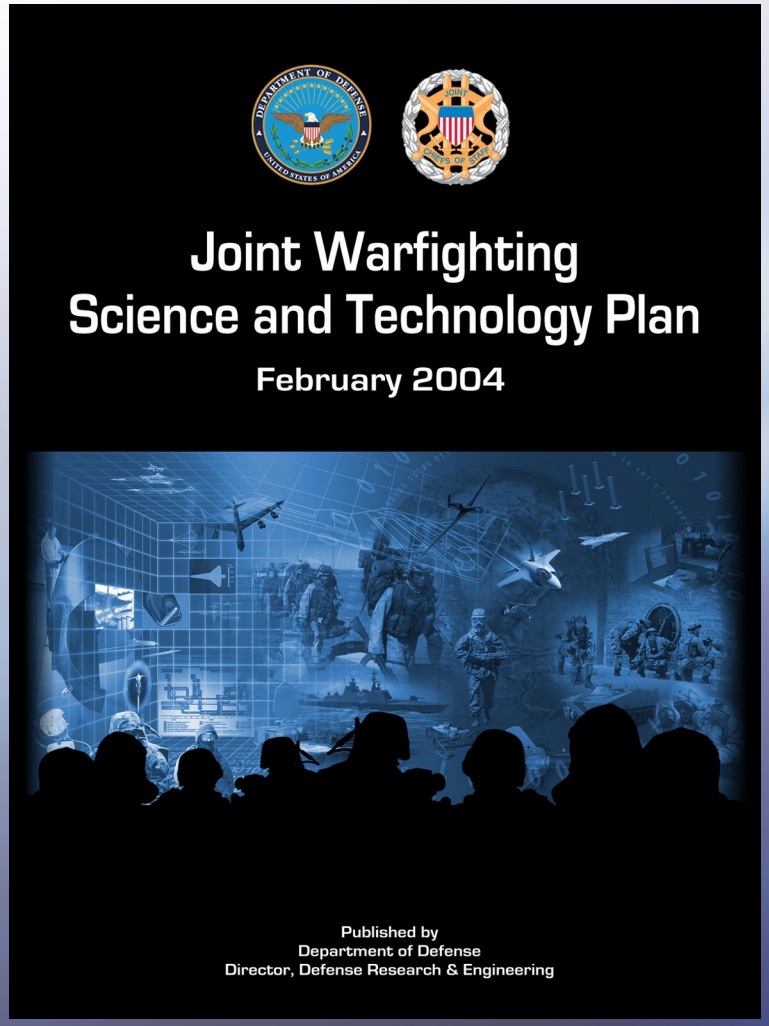
Integrated Annual Defense S&T Planning Process



ning Documents are a Key Element of Strategy Implementa n

Distribution Statement A: Approved for public release: distribution unlimited

S&T Strategy and Plans



Defense Science and Technology Strategy and Plans

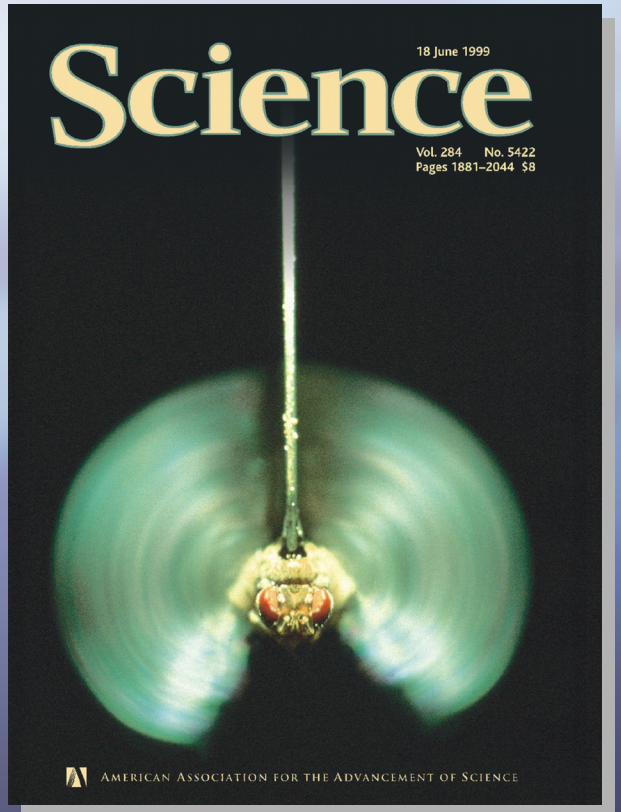
- ***Defense Research and Engineering Strategy (Being Updated)***
- ***Basic Research Plan (6.1) - BRP -(Biennial)***
- ***Defense Technology Area Plan (6.2, 6.3) - DTAP - (Biennial)***
- ***Joint Warfighting Science and Technology Plan - JWSTP (*Annual)***
- ***Defense Technology Objectives (DTO) Volume***

Distribution Statement A: Approved for public release: distribution unlimited

Basic Research Plan (BRP)

BRP-- A strategic plan to link longer term research to broad, revolutionary warfighter capabilities

- **Basic Research Areas**
  - Physics
  - Chemistry
  - Mathematics and Computer Science
  - Electronics
  - Materials Science
  - Mechanics
  - Terrestrial and Ocean Sciences
  - Atmospheric and Space Sciences
  - Biological Sciences
  - Cognitive and Neural Science

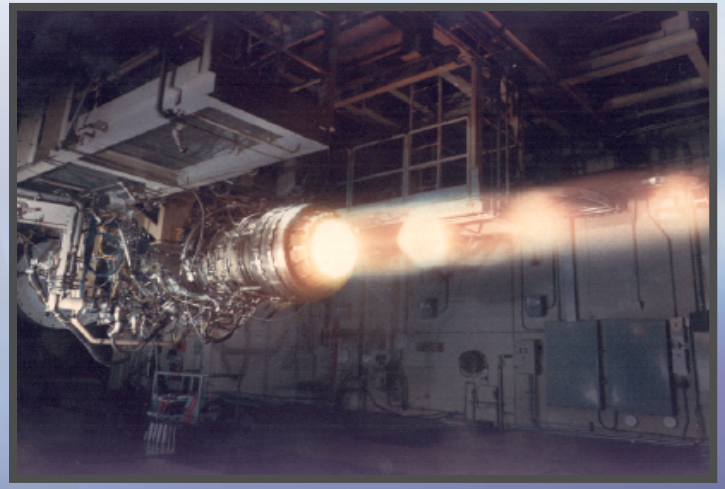


A Strategic plan guiding new technology development built around Basic Research Areas

Distribution Statement A: Approved for public release: distribution unlimited

Defense Technology Area Plan (DTAP)

- **DTAP -- A detailed plan focusing DoD science on militarily significant technology areas**



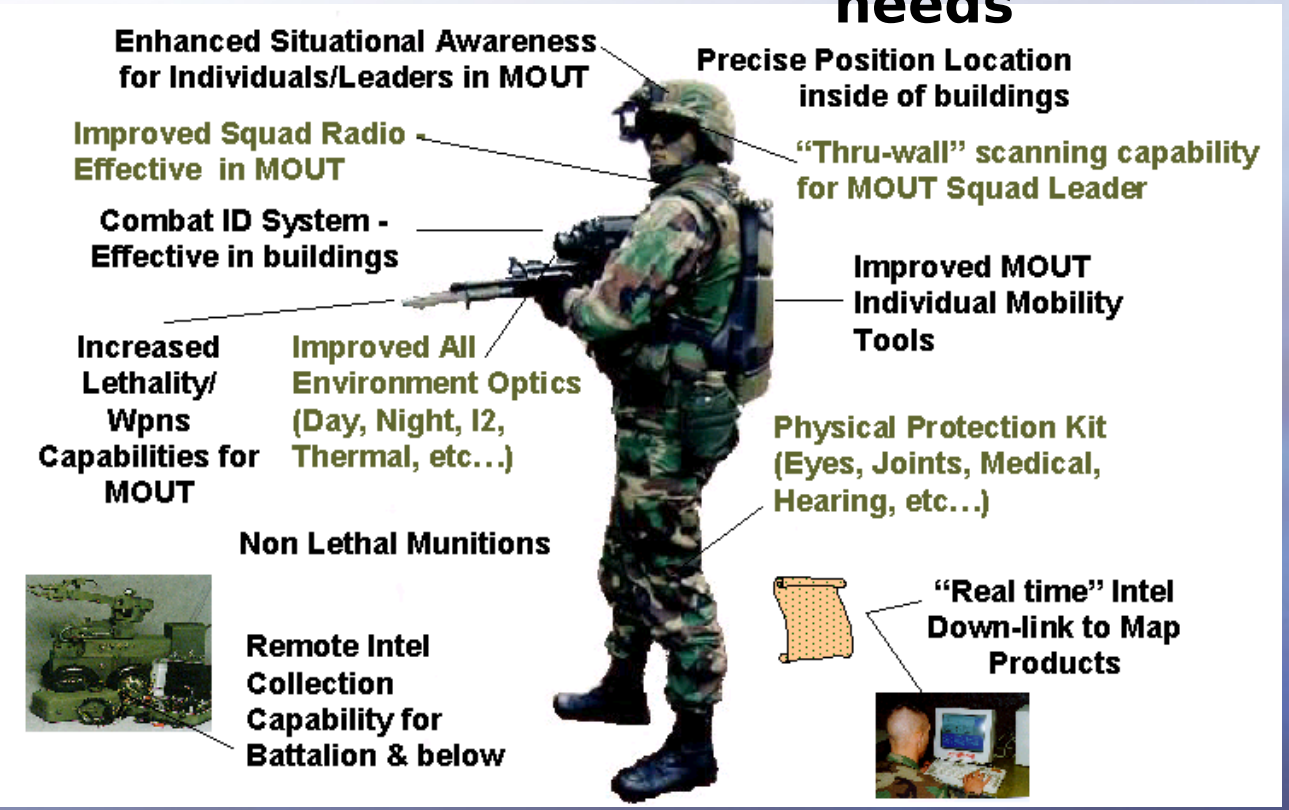
Example: DTO AP.08 Fighter/Attack Propulsion

An agreement between the S&T Community and Acquisition Customers

Distribution Statement A: Approved for public release: distribution unlimited

Joint Warfighting S&T Plan (JWSTP)

JWSTP-- Focus to blend emerging technology into warfighter needs


Enhanced Situational Awareness for Individuals/Leaders in MOUT
Precise Position Location inside of buildings
Improved Squad Radio - Effective in MOUT
"Thru-wall" scanning capability for MOUT Squad Leader
Combat ID System - Effective in buildings
Improved MOUT Individual Mobility Tools
Increased Lethality/ Wpns Capabilities for MOUT
Improved All Environment Optics (Day, Night, I2, Thermal, etc…)
Physical Protection Kit (Eyes, Joints, Medical, Hearing, etc…)
Non Lethal Munitions
"Real time" Intel Down-link to Map Products
Remote Intel Collection Capability for Battalion & below

An agreement between Joint Warfighters and S&T Community

Example: DTO E.02 *Military Operations in Urban Terrain*

Objective: Demonstrate a situation awareness/communications/ geolocation capability in restrictive environments.

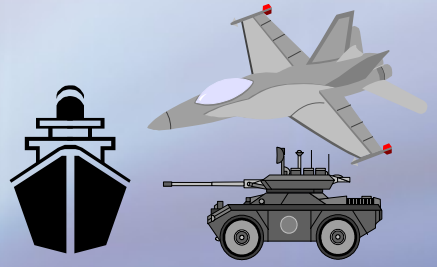
Distribution Statement A: Approved for public release; distribution unlimited.

Near-Term S&T Operator Involvement

All Services are evolving their technology development and acquisition processes to a "systems approach"

FROM

S&T



Acq

TO

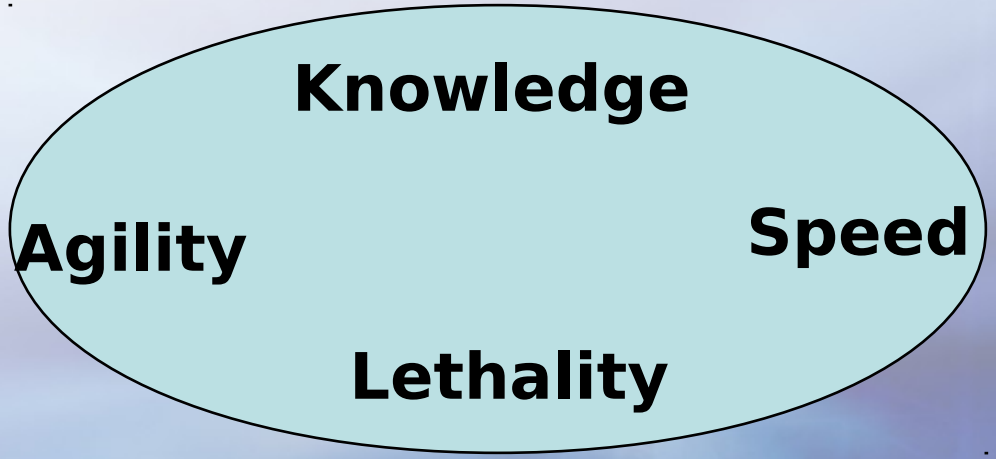
Right

- ***Technolog***
- ***People***
- ***Time***

Distribution Statement A: Approved for public release: distribution unlimited

Transformation Technology Initiatives

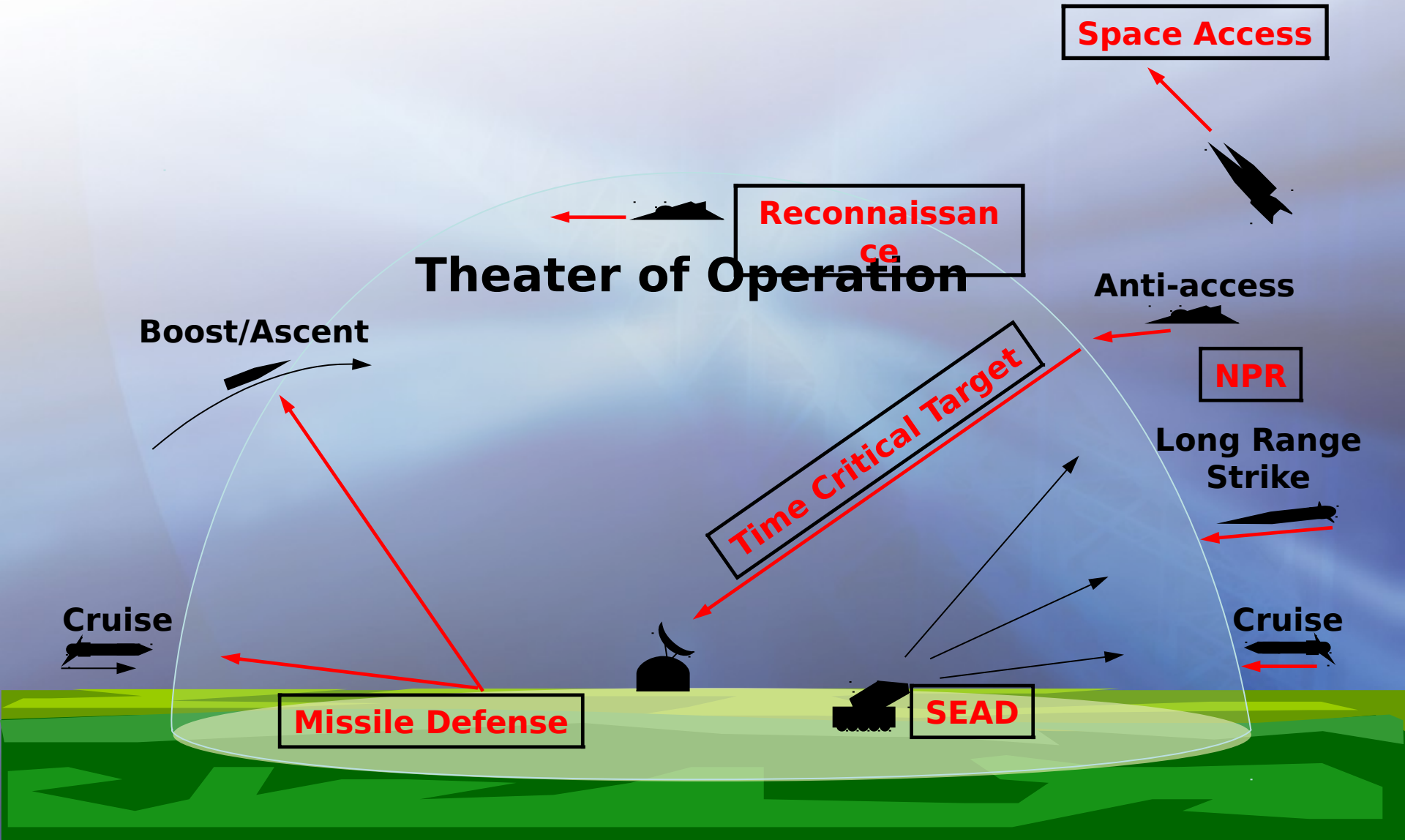
- **Transformation Attributes**



- **Transformation Technology Initiatives**
  - **National Aerospace Initiative**
  - **Energy and Power Technologies**
  - **Surveillance and Knowledge Systems**

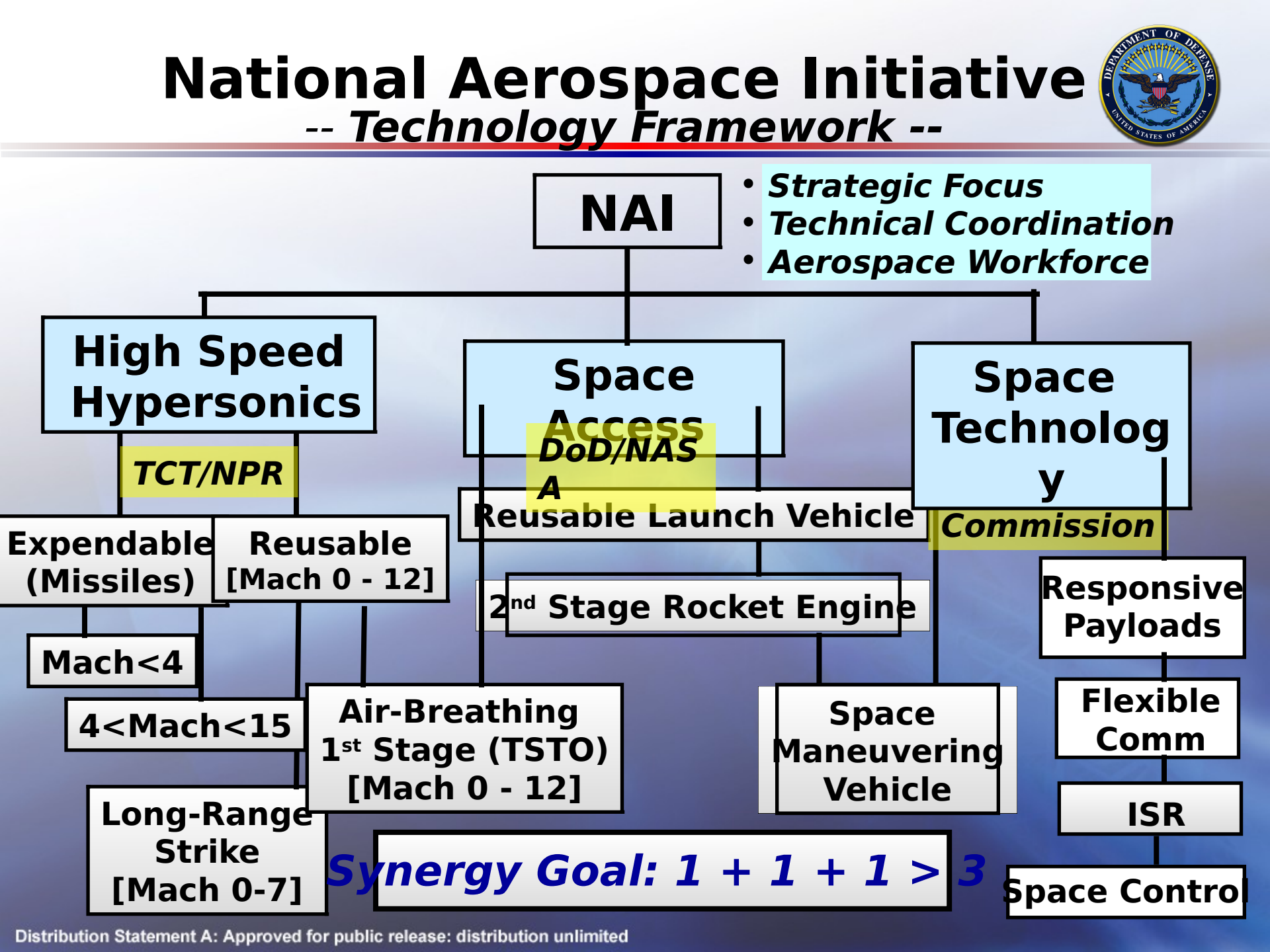
Distribution Statement A: Approved for public release: distribution unlimited

Value of Speed



National Aerospace Initiative

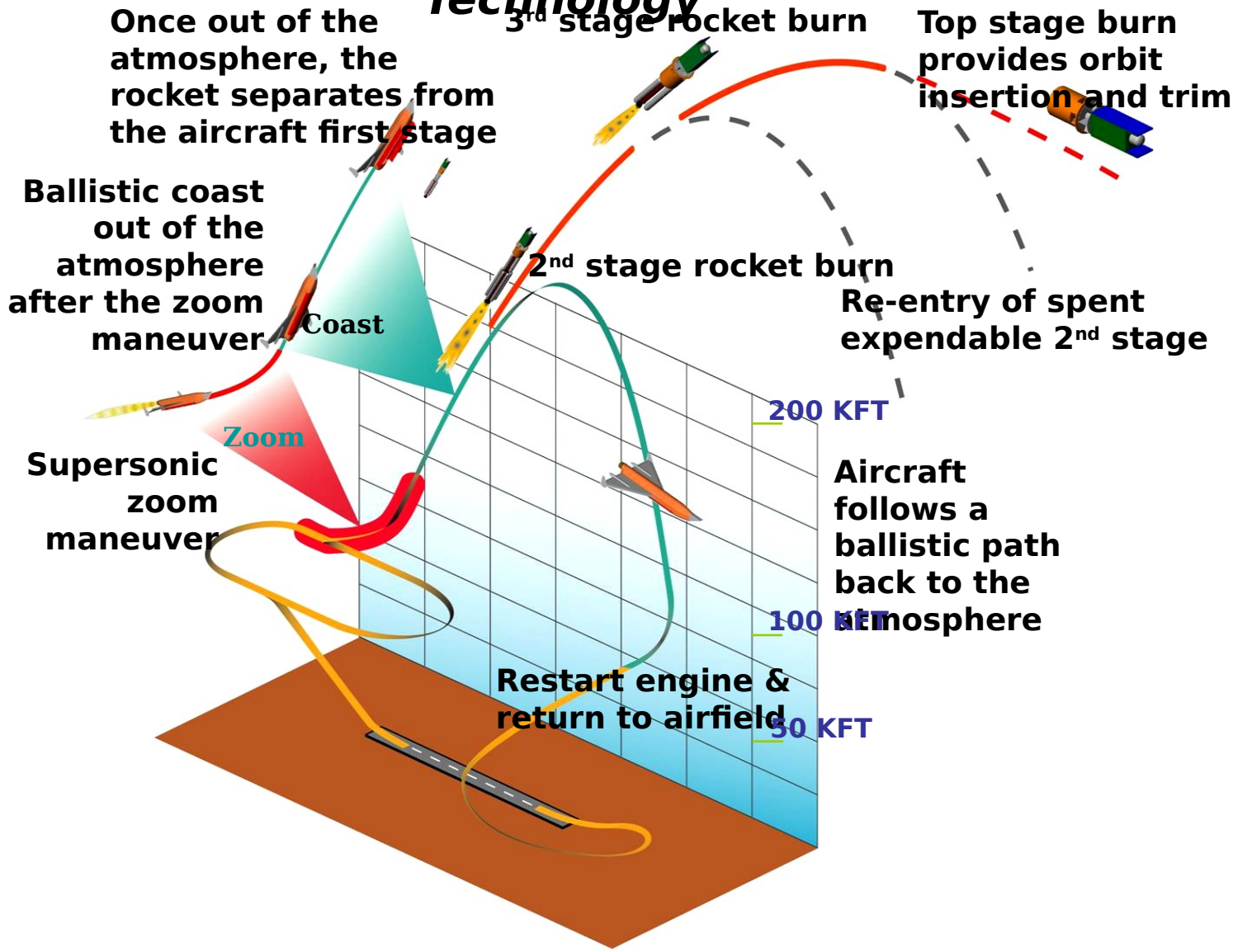
-- *Technology Framework* --



Distribution Statement A: Approved for public release: distribution unlimited

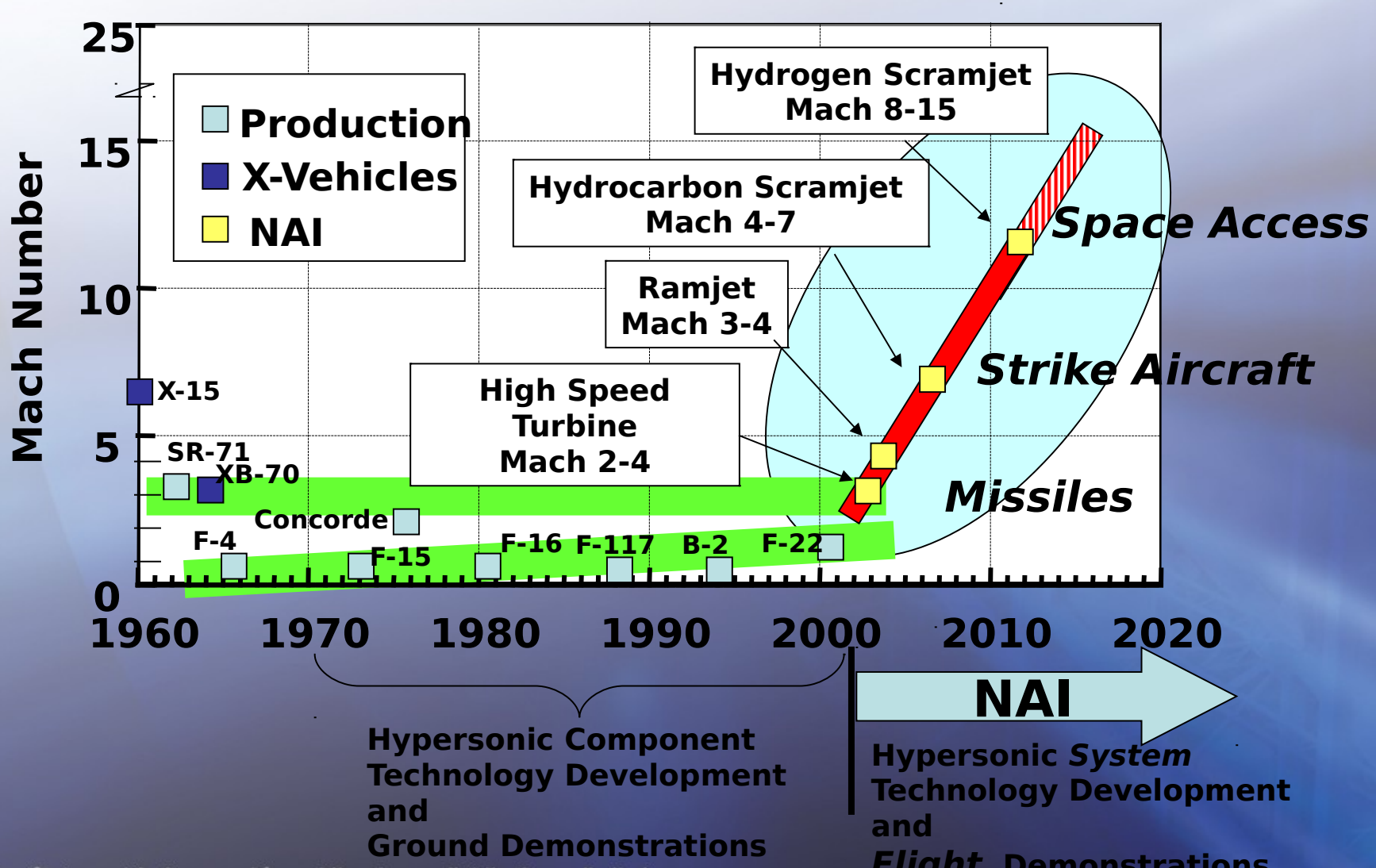
DARPA RASCAL Program

High Speed / Hypersonics, Space Access, Space Technology


Once out of the atmosphere, the rocket separates from the aircraft first stage
3rd stage rocket burn
Top stage burn provides orbit insertion and trim
Ballistic coast out of the atmosphere after the zoom maneuver
Coast
2nd stage rocket burn
Re-entry of spent expendable 2nd stage
Zoom
200 KFT
Supersonic zoom maneuver
Aircraft follows a ballistic path back to the atmosphere
100 KFT
Restart engine & return to airfield
30 KFT

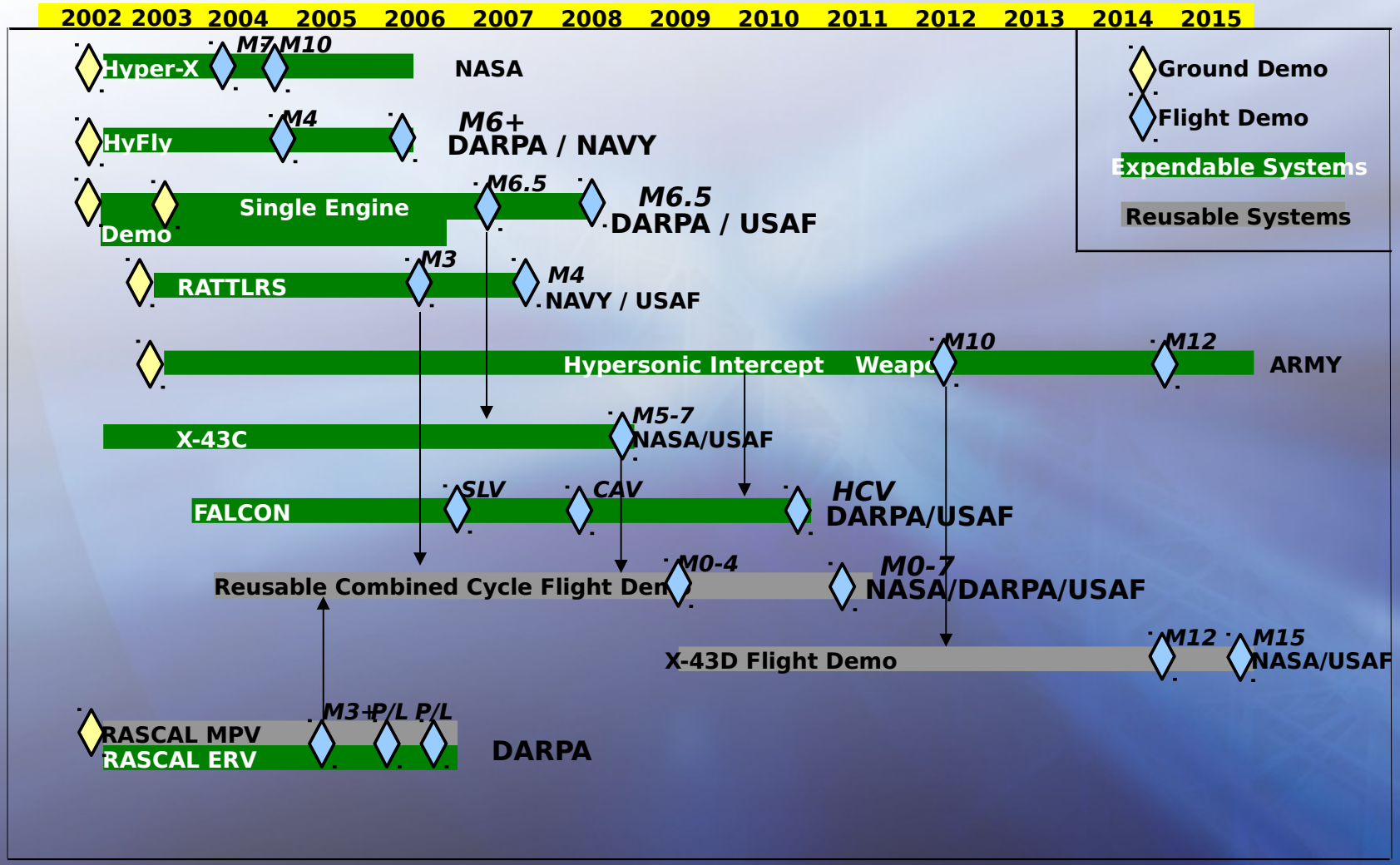
Distributio

National Aerospace Initiative



Distribution Statement A: Approved for public release: distribution unlimited

Test/Demonstrator Roadmap
High Speed/Hypersonics and Space Access



UNCLASSIFIED

Distribution Statement A: Approved for public release: distribution unlimited

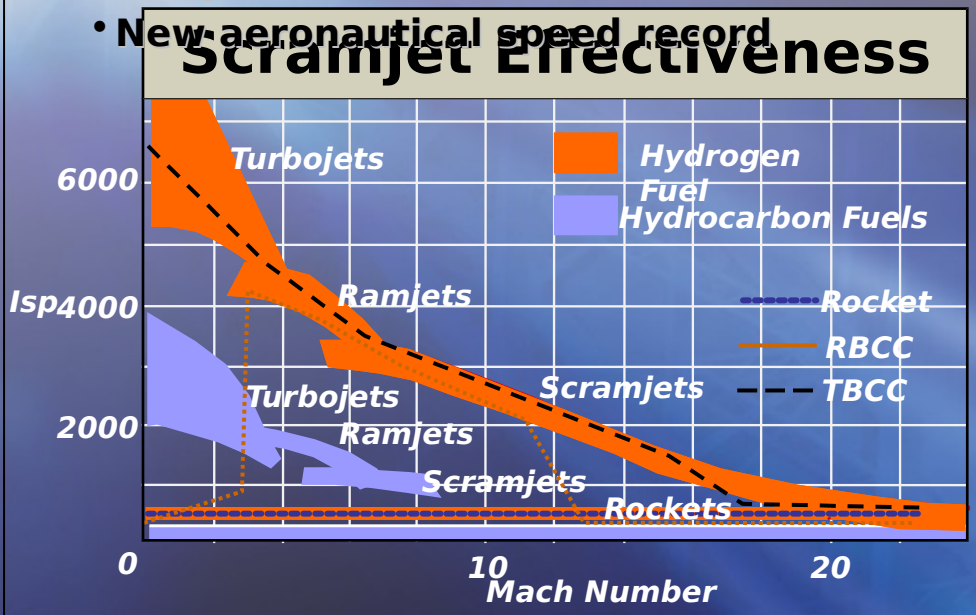
X-43A Program

Hypersonic flight: March 27, 2004

- 8 sec at Mach 7
- 95,000 ft altitude
- first controlled accelerating flight at Mach 7 under scramjet power
- first air breathing scramjet-powered free flight
- first successful stage separation at high dynamic pressure of two non-axisymmetric vehicles
- New aeronautical speed record

Team:

- NASA Langley
- NASA Dryden
- Boeing
- ATK GASL (formerly MicroCraft)
- Orbital Sciences
- Army
- Navy
- Air Force



Distribution Statement A: Approved for public release: distribution unlimited

High Speed / Hypersonics

HyFly

(DARPA / Navy)
Ground Testing Began - May 30, 2002

Full Scale, Fully Integrated – 80 Tests

Data gathered at Mach 3.5, 4.1, 6.2, 6.5

Altitude 55kft up to 100kft

Distribution Statement A: Approved for public release: distribution unlimited

Single Engine Demonstration
DARPA/Air Force Flight Test Program

HyTech

AF Ground Testing

145 Tests (2001 – 2003)

Film: Mach 4.5 Test

Mach 6-6.5 Testing in Progress

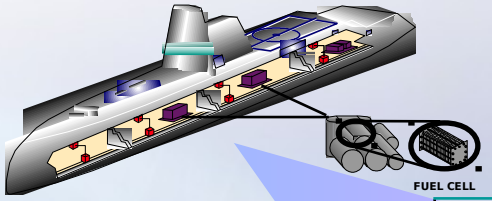
Distribution Statement A: Approved for public release: distribution unlimited

Energy & Power Technologies…
Enabling a More Electric Force

POWER GENERATION
- Fuel Cells & Fuel Reforming
- Novel Power

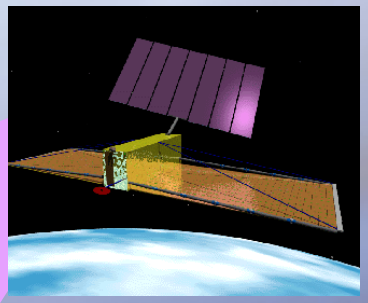
ENERGY STORAGE
- Batteries
- Capacitors

POWER CONTROL AND DISTRIBUTION
- Switching & Conditioning
- Power Transmission & Distribution
- Thermal Management

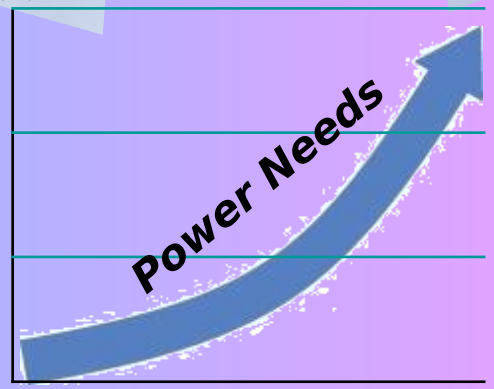


Electric Warship

More Electric Aircraft



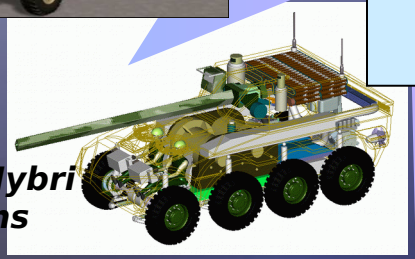
Space Based Radar



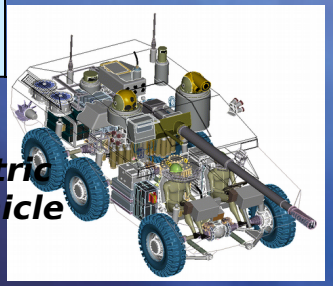
High Power Microwave

Warrior

New Operational Capabilities



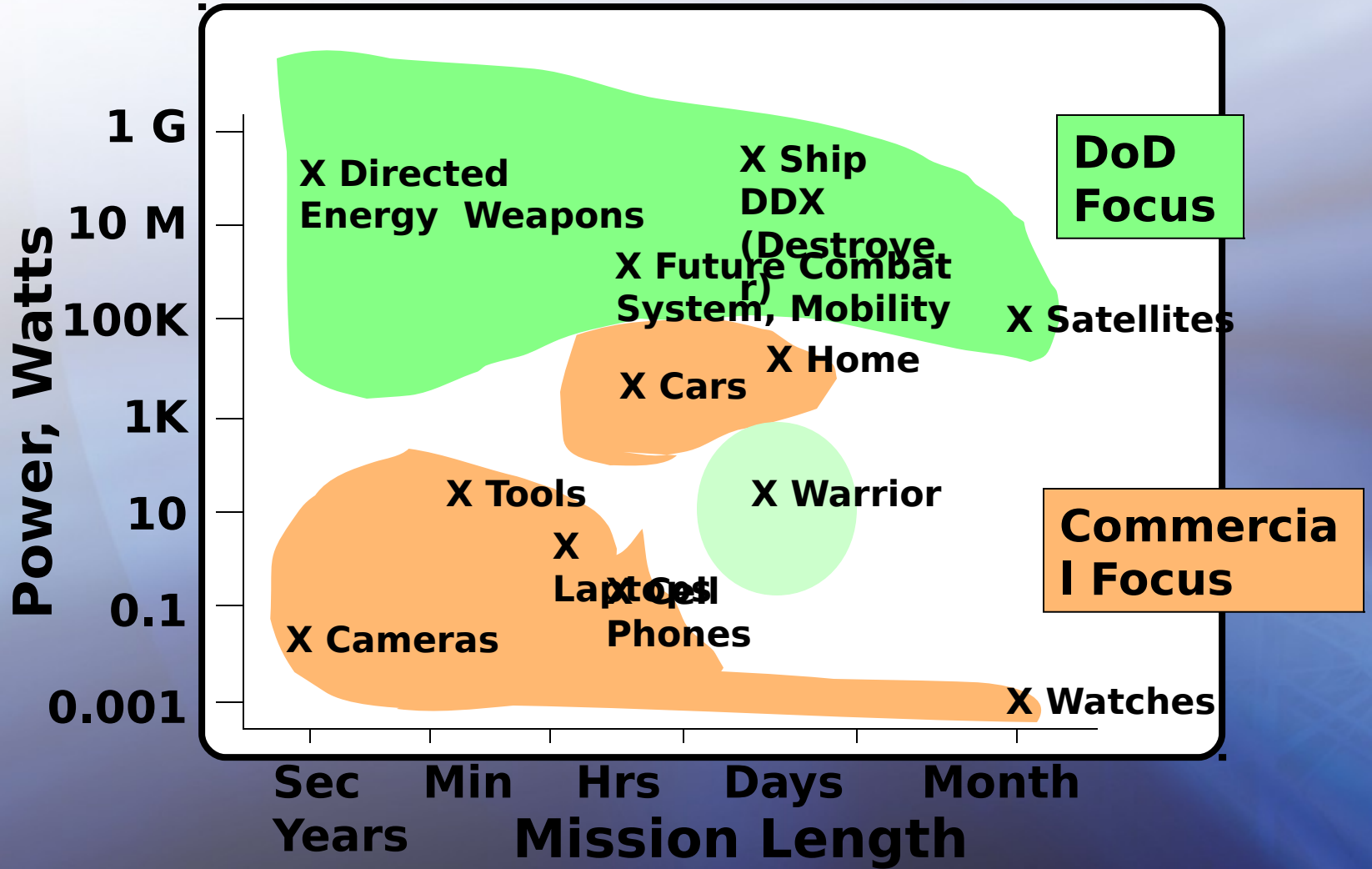
Electric/Hybrid Weapons



Hybrid/Electric Combat Vehicle

Distribution Statement A: Approved for public release: distribution unlimited

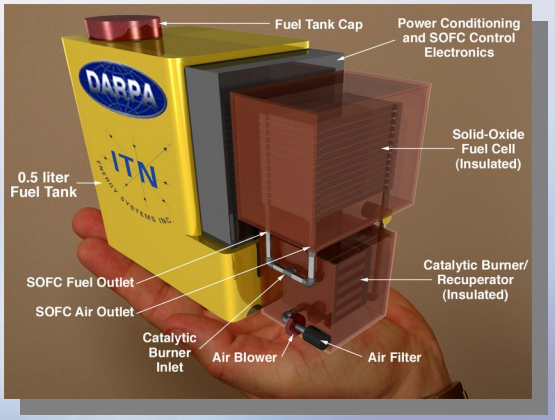
Energy and Power Technologies



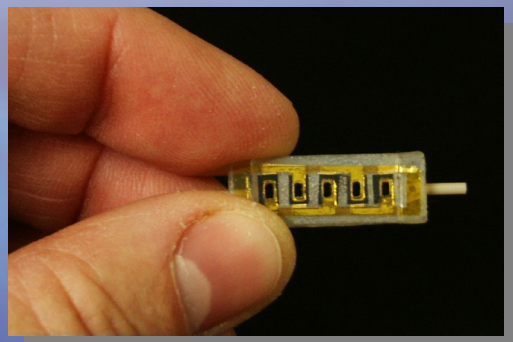
Distribution Statement A: Approved for public release: distribution unlimited

Miniaturized Electric Power

Direct Methanol Fuel Cell (Army)

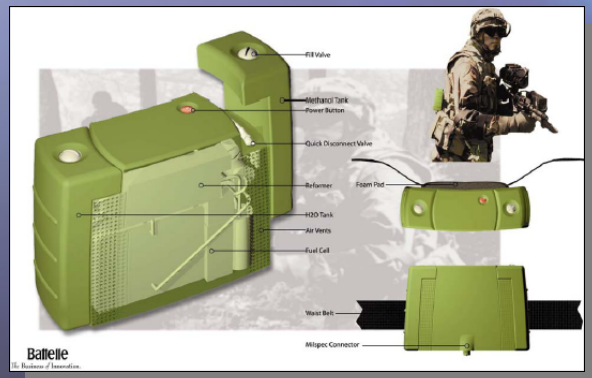


Palm Power Program (DARPA)



MEMS-based Fuel Cell (DARPA / Air Force)

Micro-Channel Methanol Reformer & Fuel Cell (Marine Corps)



Distribution Statement A: Approved for public release: distribution unlimited

Energy & Power Technologies
Project and Sustain

Description:
Revolutionize energy and power components for high impact and accelerated fielding of critical military platforms and weapons

Major Goals:
- **2X - 10X increased Power Generation in a decade**
- **2X - 6X increased Energy Storage in a decade**
- **Power Control and Distribution: high power switches, control and distribution and high heat flux, large area thermal management**

Meeting 2001 QDR's Operational Goals:
- **Anti-Access capability**
- **Minimize Logistics Footprint**
- **Dominant Maneuver**
- **Land-based Autonomous and Semi-Autonomous Systems**

New / Enhanced Warfighting Capabilities:
- **Silent watch / movement for stealth operations**
- **Greater lethality with advanced weapons**
- **Greater survivability**
- **Electric launch and recovery of aircraft helps control forces applied to aircraft**
- **Improved efficiency, all electric systems, and commonality reduce logistical burdens**

Distribution Statement A: Approved for public release: distribution unlimited

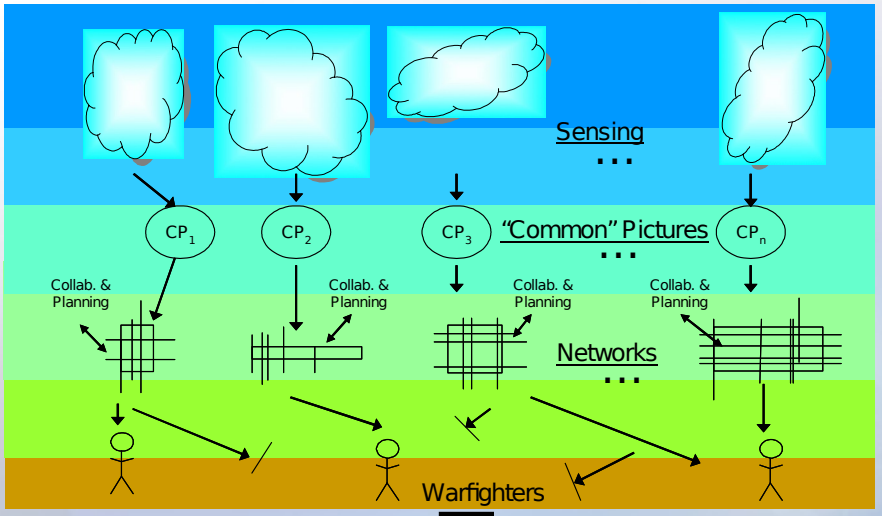
Surveillance & Knowledge Systems

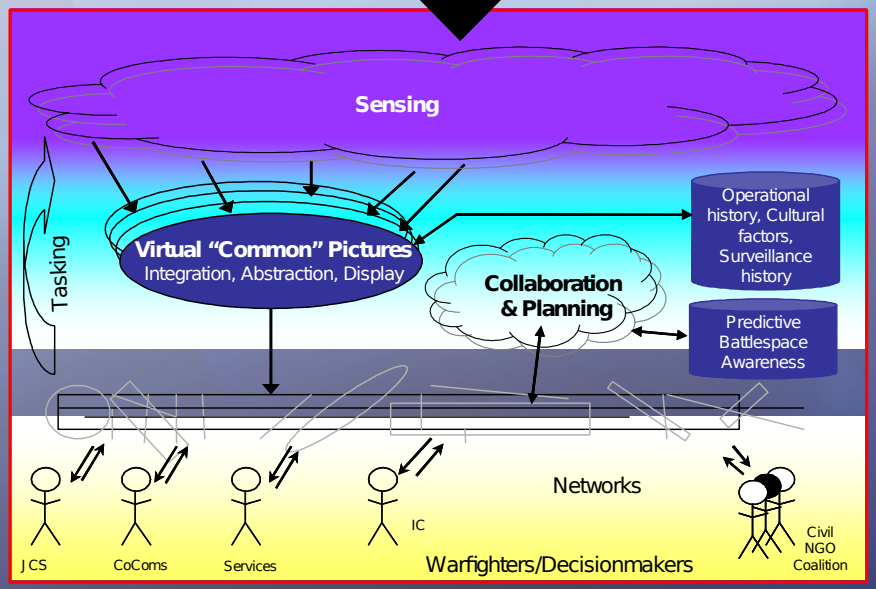
Information and Decision Dominance achieved through integrated C4ISR technologies that enable seamless, interoperable, knowledge-based, and assured Joint & Coalition Network-Centric Operations & Warfare.

- ***Sensing:***
  Management and tasking of pervasive, persistent sensors for enhancing battlespace knowledge
- ***Comms & Networking:***
  Guaranteed, 365x24x7, mobile, information access and delivery (always-on "internet dial tone")
- ***Knowledge Management:***
  Dramatically improved speed of command through integrated Common Picture, Collaboration, and Planning
- ***Information Security (Cyber Ops):***
  Network protection, information assurance; offensive disruption

Distribution Statement A: Approved for public release: distribution unlimited

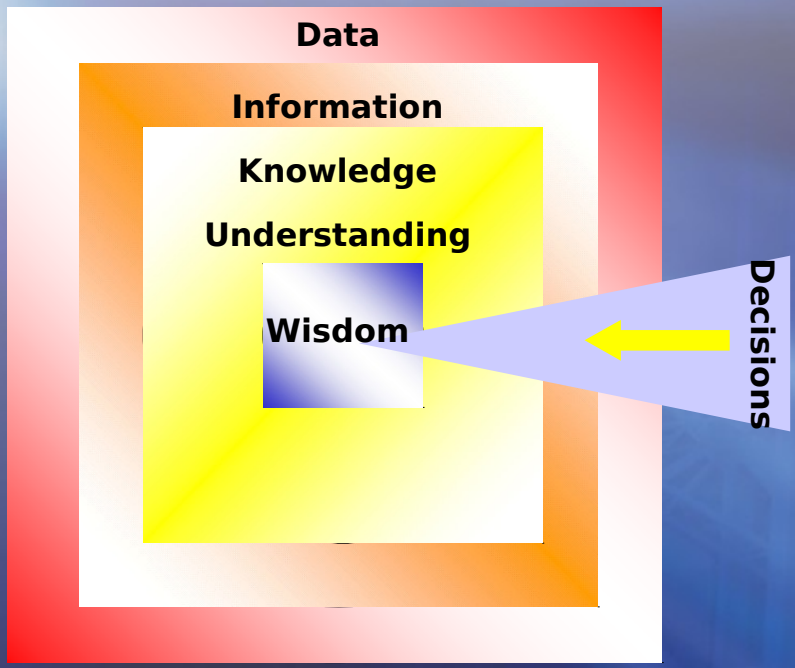
Surveillance & Knowledge
Enabling Integrated C4ISR





Technology Foci

- Adaptive Networks
- Ubiquitous Sensors
- Decision Aids



Distribution Statement A: Approved for public release: distribution unlimited

Surveillance & Knowledge Metrics:
Key Elements

- **Sensing, Detection, & Tracking Effectiveness**
- **Common Picture Quality**
- **Decision Quality & Timeliness**
- **Network Coverage**
- **Interoperability & Flexibility**
- **Information Security, Survivability, and Response**

There is no single "Mach Number" metric to gauge success in C4ISR.

Distribution Statement A: Approved for public release: distribution unlimited

DoD Combating Terrorism Technology Task Force (CTTTF)

- ***Task Force Established by DDR&E - Sept 19, 2001***

- ***Collaborative effort between DoD Service/Agency Science & Technology (S&T) Organizations, coordinating with:***
  - Joint Staff
  - Combatant Commanders (CoComs)
  - Other Federal Agencies

- ***Objectives:***
  - Identify needs and technologies for the Global War on Terrorism (GWOT)
  - Prioritize technology options with users
  - Rapidly transition and field systems
  - Coordinate Force Protection technology solutions

Distribution Statement A: Approved for public release: distribution unlimited

Phase 1 (Sep 2001 – Feb 2002)

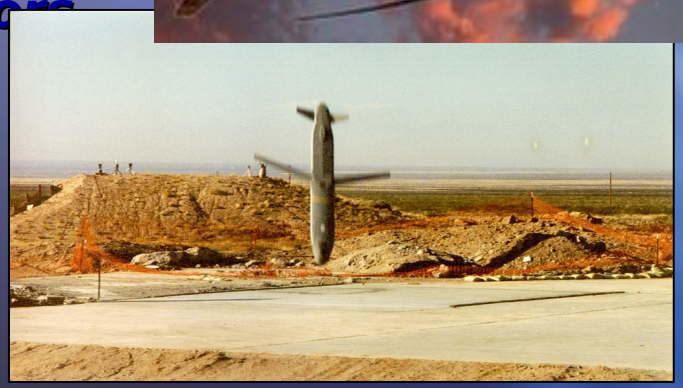
Key Near-Term Technologies

Thermobaric Weapon

- Chemistry to Fielded System – 90 Days
- Teaming:
  - Defense Threat Reduction Agency
  - Air Force Research Laboratory
  - Air Armament Center
  - Naval Surface Warfare Center
  - Air Combat Command
  - DoE / Lawrence Livermore National Lab

Deployed & Employed in Operation Enduring Freedom (OEF)

Conventional Air Launched Cruise Missile (CALCM) Penetrator



Deployed / Employed in Operation Iraqi Freedom (OIF

Nuclear Quadrupole Resonance

Distribution Statement A: Approved for public release: distribution unlimited

Water Purification System/Water Pen Unit

Fiscal Year 2003 Technology Transition Initiative (TTI)

Participants:
Defense S&T Source: DARPA

Source of Procurement Funding: Various operational units (GSA Catalog)

Technology:
Mixed oxidants electrochemically generated from common table salt via several small lithium camera batteries kill a wide range of resistant microorganisms.

Schedule:
FY03: Procured 2,494 water purification pens and distributed them throughout the Services and U.S. Special Operations Command (SOCOM).

FY 04: Procure and distribute 4,157 additional pens.

Comments:
The pen would enable soldiers to treat up to 300 liters of any available, non-brackish water source, eliminating the risk of their exposure to diseases and bio-chemical pollutants.

Distribution Statement A: Approved for public release: distribution unlimited

Phraselator

Capabilities:

- Translation of spoken English to the user selected foreign language
- Supports one-way spoken dialog with gesture response
- Permits soldiers to interact with native populations
- New phrases can be added to the system by soldiers in the field using a laptop PC

Available Languages

Albanian	Arabic	Azerbajani
Armenian	Bulgaria	Chinese Mandarin
Cambodian	Croatian	Japanese
Czech	Dari	Polish
Korean	Macedonian	Portuguese
Punjabi	Pushtu	Brazil/Euro
Russian	Rwandan	Serbian
Singhalese	Dutch	English
Farsi	French	Georgian
German	Thai	Haitian Creole
Hindi	Hungarian	Indonesian
Italian	Slovak	Slovenian
Spanish	Swahili	Swedish
Tagalog	Turkish	Hebrew
Urdu	Vietnamese	Woleaian
		Iranian

Status:

- Fielded for pilot testing. Improved hardware and software under development.
- LASER ACTD is investing in two-way speech capability for future fielding

Distribution Statement A: Approved for public release: distribution unlimited

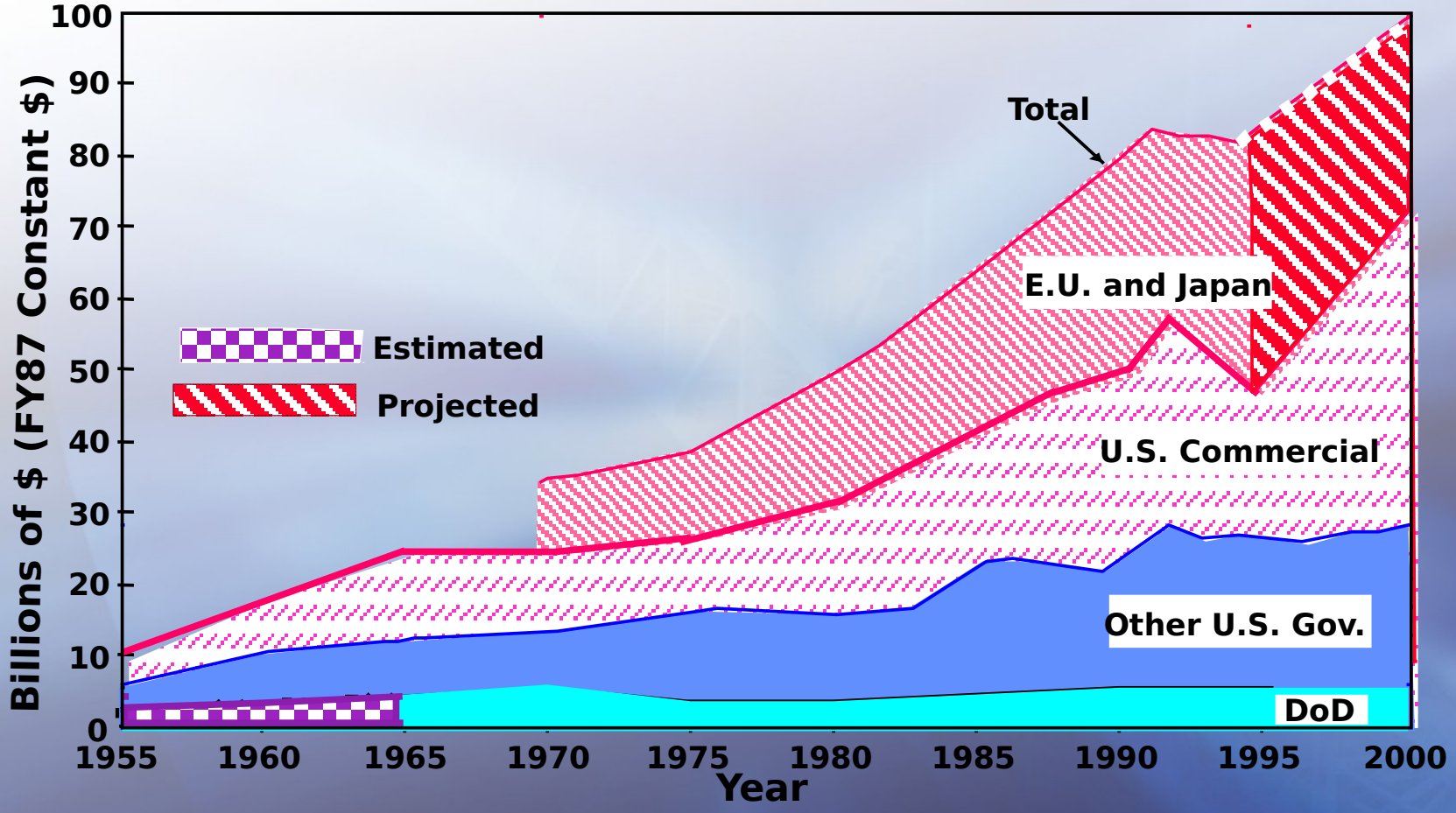
Dragon Eye (DE)-ATR
(Chem-Bio-Video Advanced Tactical Recce)

- **Visual Battle Damage Assessment (BDA)**
- **Real time chemical agent detection and data transmission to ground station**
- **Collection of biological agents**
- **Ground-based bioagent analysis 30 - 45 min**

Deployed in Operation Iraqi Freedom

Distribution Statement A: Approved for public release: distribution unlimited

U.S. and Worldwide Research Base Since WWII



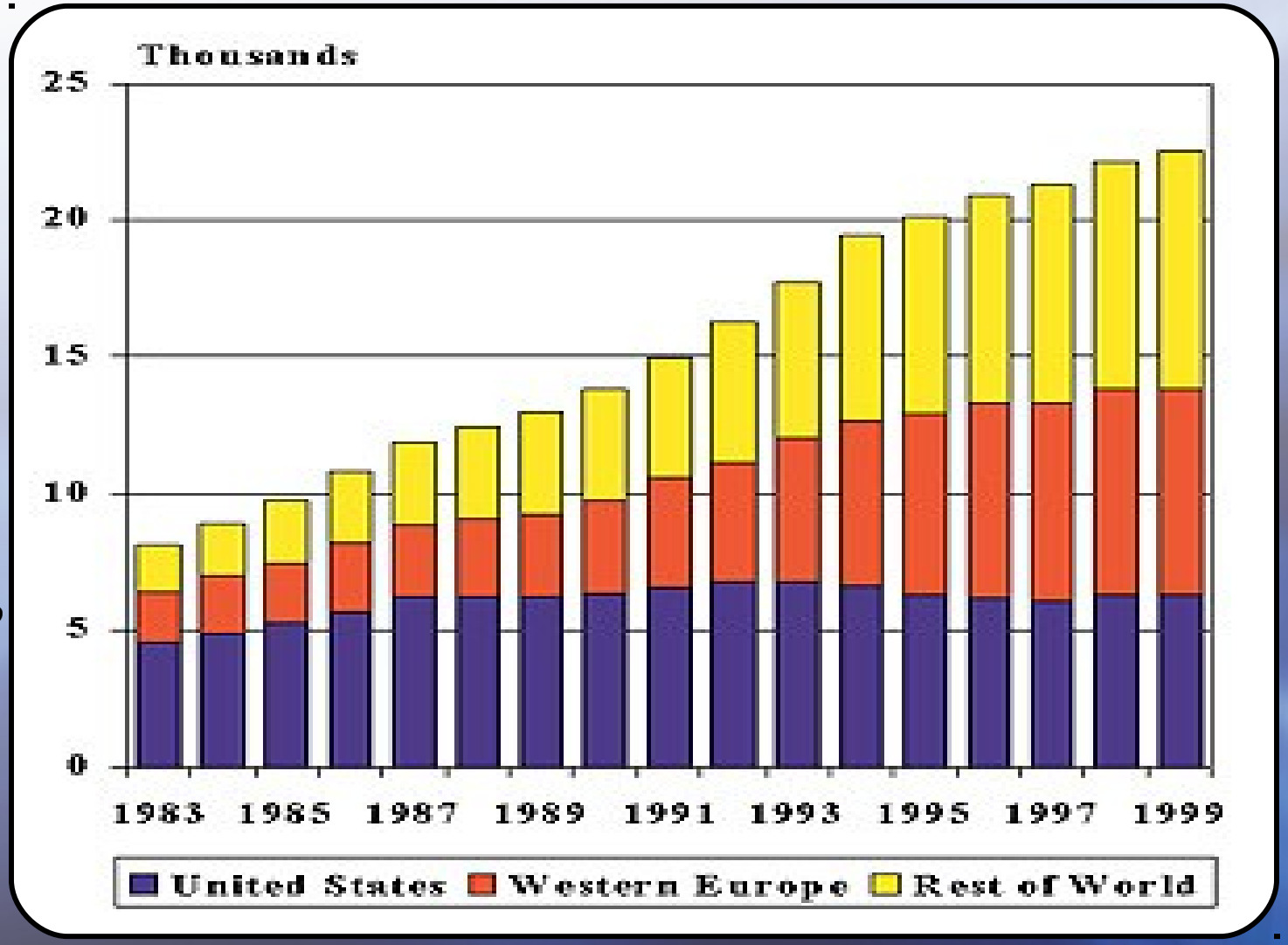
Source: Report of the Defense Science Board Task Force on the Technology Capabilities of Non-DoD Providers; June 2000; Data provided by the Organization for Economic Cooperation and Development & National Science Foundation

Distribution Statement A: Approved for public release: distribution unlimited

Physical Review Trends

Physical Review & Physical Review Letters

Total Submissions



Source: American Physical Society - APS News August/September 2000

Distribution Statement A: Approved for public release: distribution unlimited

DoD S&E as % of Fed Workforce

Source: Pre-release - OPM data for NSF pub, Table B-14. Federal scientists and engineers, by agency and major occupational group: 1994-1998

	1994	1995	1996	1997	1998
Total S&Es	48.0%	47.6%	47.6%	46.6%	45.8%
All sci	28.8%	28.6%	28.8%	28.0%	27.4%
Comp/Math sci	54.0%	51.6%	50.4%	48.8%	47.6%
Life sci	10.8%	11.7%	12.0%	12.2%	12.0%
Physical sci	29.4%	29.2%	30.2%	28.2%	27.5%
Social sci	21.2%	21.6%	21.7%	21.9%	21.4%
All eng	67.1%	67.2%	67.7%	67.3%	67.0%
Aerospace	46.3%	45.5%	46.7%	46.7%	45.2%
Chemical	59.5%	59.6%	62.1%	61.3%	60.8%
Civil	59.7%	61.3%	62.1%	62.1%	61.8%
EE&Comp	79.0%	79.4%	79.9%	79.4%	79.4%
Industrial	86.0%	85.2%	84.8%	83.8%	82.4%
Mechanical	88.1%	88.2%	88.5%	88.2%	88.2%
Other eng	54.3%	54.0%	54.5%	54.5%	54.7%

Distribution Statement A: Approved for public release: distribution unlimited

DoD Percent of Federal Research

Basic and Applied Research (FY00)

	Fed Total	Univ. Research	Univ. Basic	Univ. Applied
Aeronautical	38%	52%	37%	71%
Astronautical	14%	28%	90%	3%
Electrical Engineering	81%	68%	69%	68%
Mechanical Engineering	71%	67%	67%	72%
Metallurgy & Materials	36%	37%	33%	59%
Civil Engineering	35%	14%	11%	20%
All Engineering	39%	33%	32%	36%
Mathematics	15%	14%	14%	15%
Computer Science	35%	37%	12%	88%
All Fields of	13%	7%	7%	8%

Source: Federal Funds for R&D, NSF Report #02-321

Distribution Statement A: Approved for public release: distribution unlimited

updated 8/02/02, KT

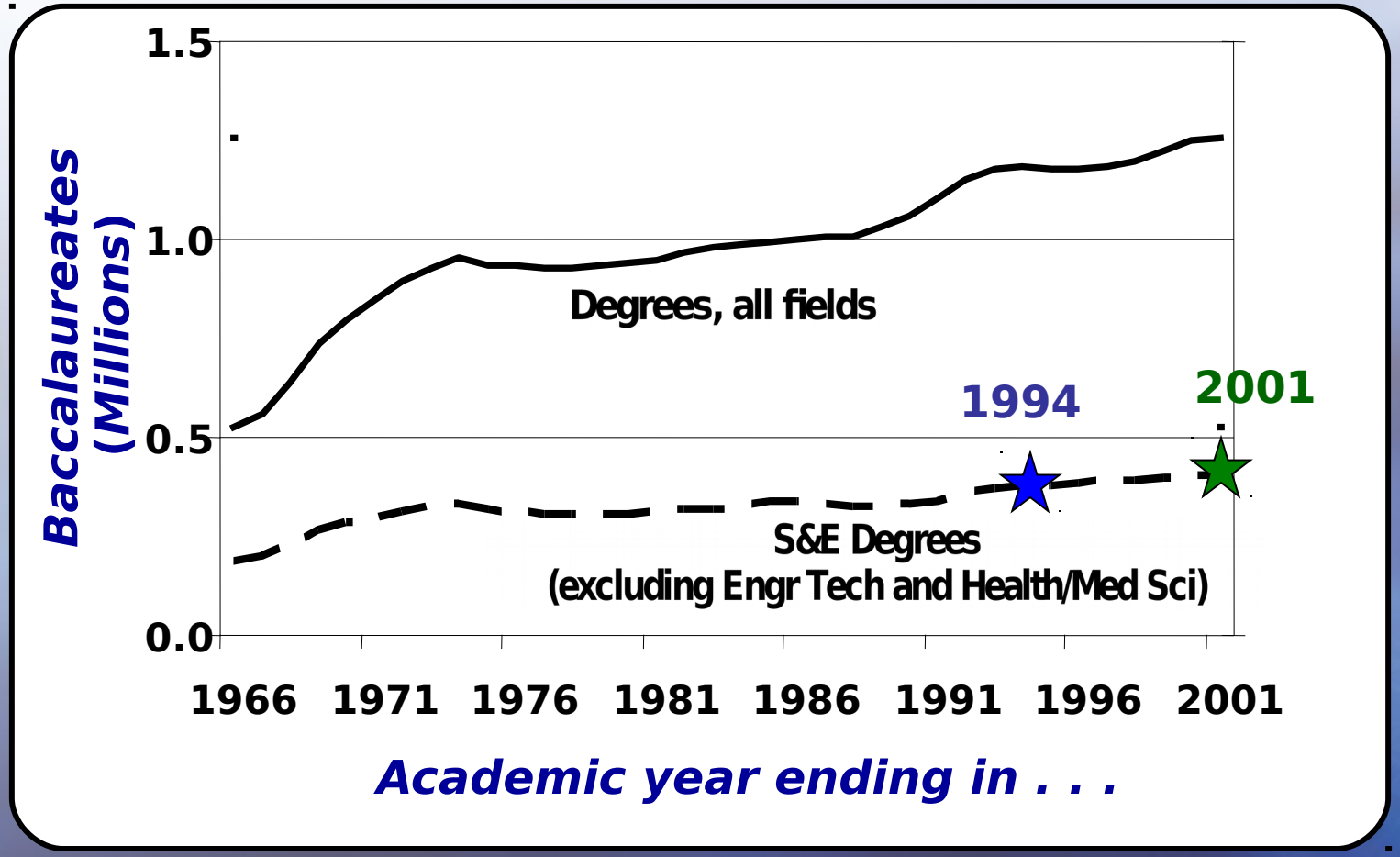
Overall S&E Demand Projections 2000-2010

From "Occupational Outlook Handbook" Bureau of Labor Statistics

DoD Defense-Related Disciplines	Projected growth in S&E Demand
Computer Software Engineering	36%
Computer Hardware Engineering	21-35%
Aerospace Engineering	10-20%
Electrical & Electronic Engineering	10-20%
Mechanical Engineering	10-20%
Chemistry/Materials Science	10-20%
Physics	10%
Chemical Engineering	3-9%
Industrial Engineering	3-9%
Materials Engineering	3-9%
Nuclear Engineering	0-2%
Mathematics	-1%

.S. Production of S&E Graduates*

U.S. College and University Graduates, 1966-2001



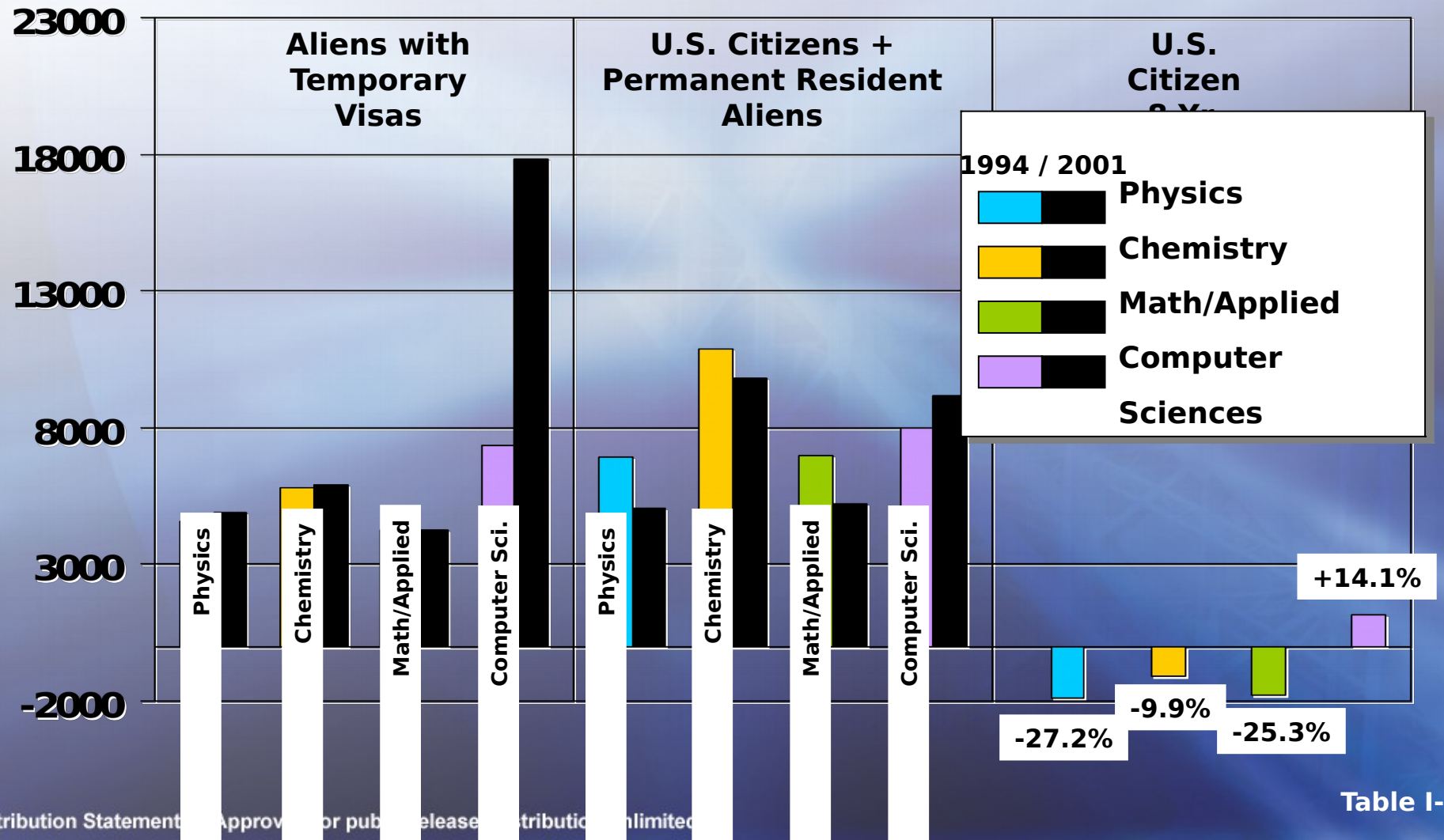
**Source: Data provided by the NSF, September 2003*

Distribution Statement A: Approved for public release: distribution unlimited

U.S. University Trends in Defense-Related S&E Graduate Student Enrollment (1994-2001)

**Source: National Science Foundation – Graduate Students and Post Doctorates in Science and Engineering: Fall 2001*

Science Disciplines



Distribution Statement Approv or pub elease tributio nlimited

Table I-

U.S. University Trends in Defense-Related S&E

Graduate Student Enrollment (1994-2001)

**Source: National Science Foundation – Graduate Students and Post Doctorates in Science and Engineering: Fall 2001*

Engineering Disciplines

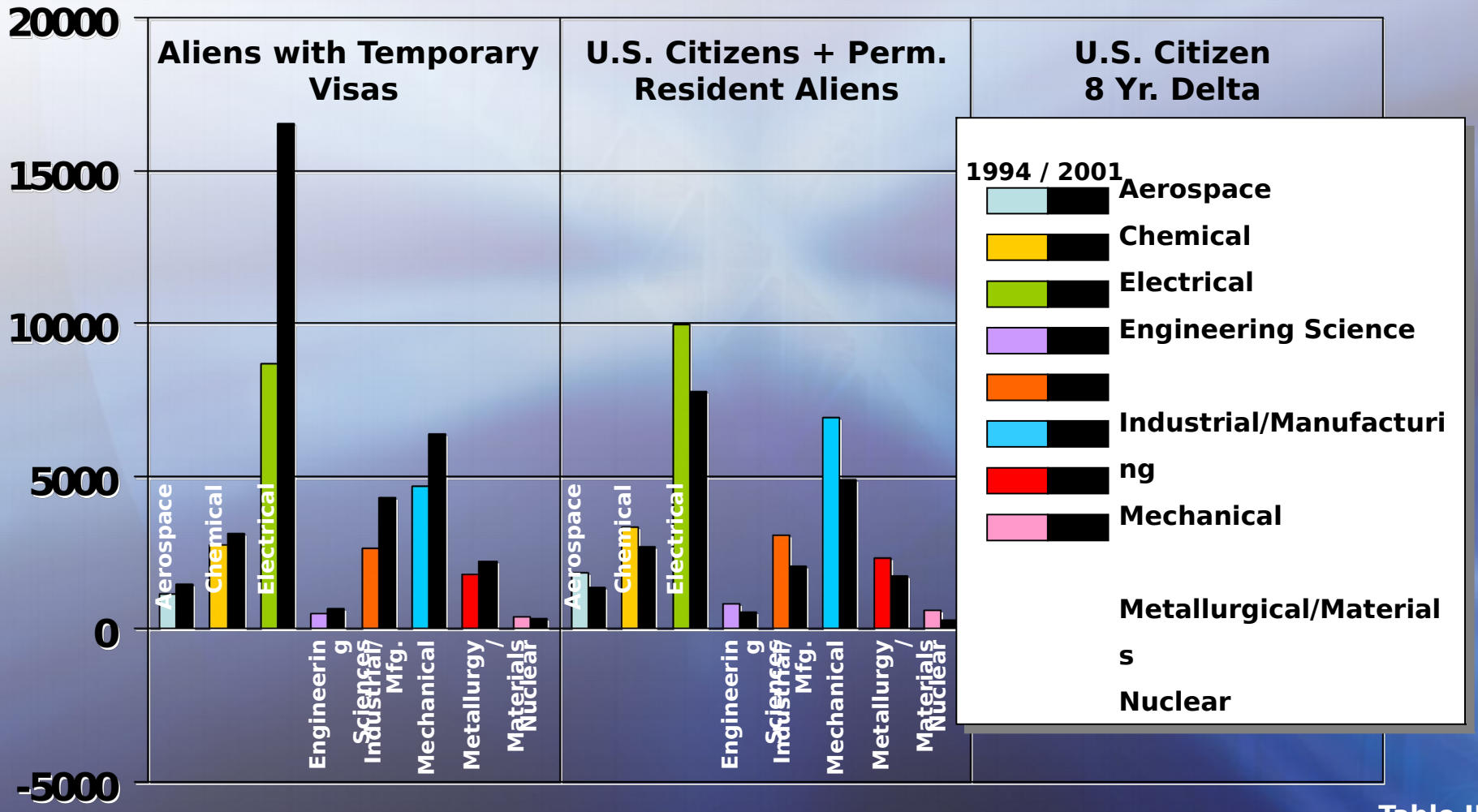
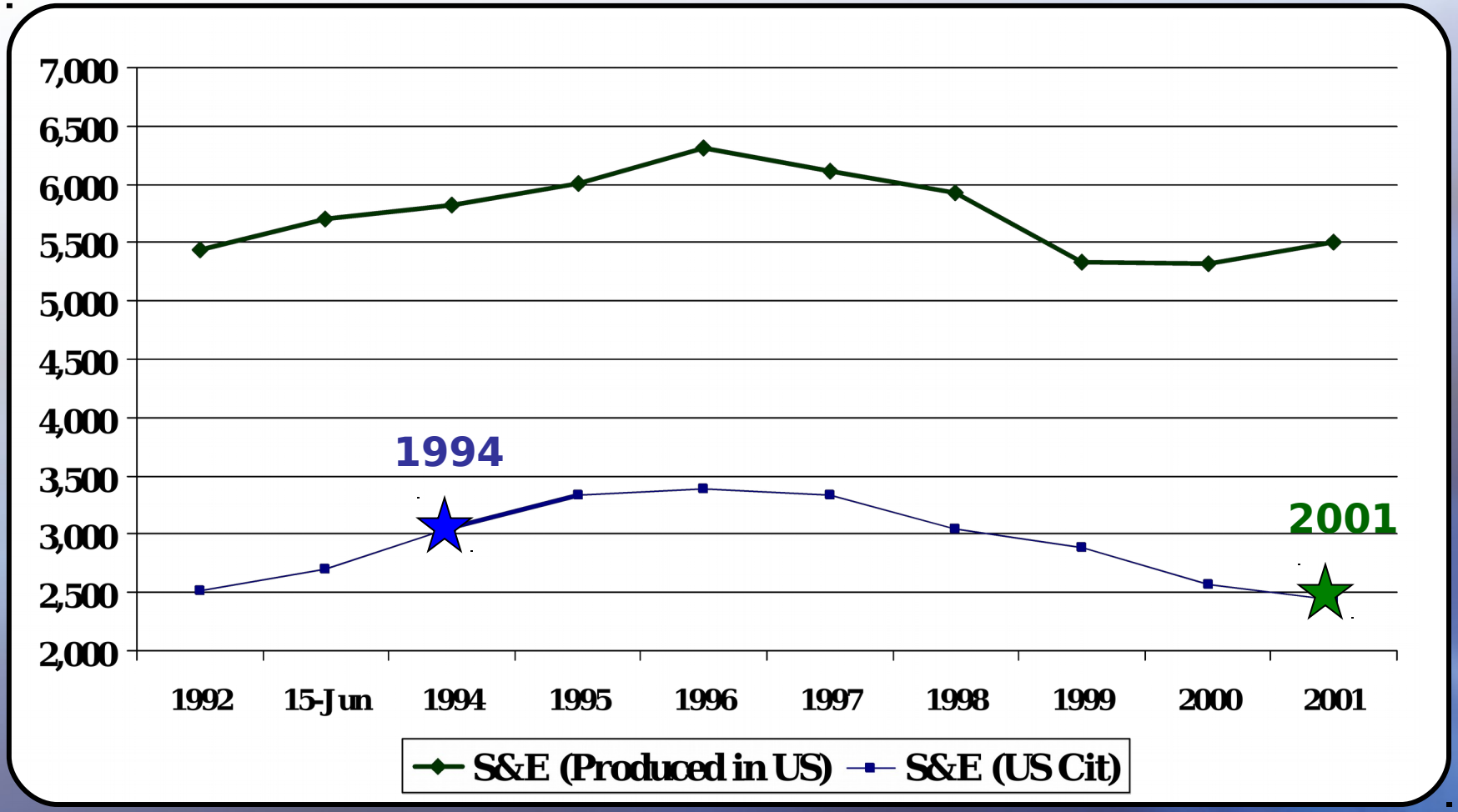


Table III

Distribution Statement A: Approved for public release: distribution unlimited

U.S. Engineering PhD's Awarded



Source: Data provided by the NSF, September 2002

Distribution Statement A: Approved for public release: distribution unlimited

U.S. S&E Ph.D Production Trends (1994-2001)

*Source: National Science Foundation – Science and Engineering Doctorate Awards, 2002

All U.S. S&E Discipline Doctoral Production

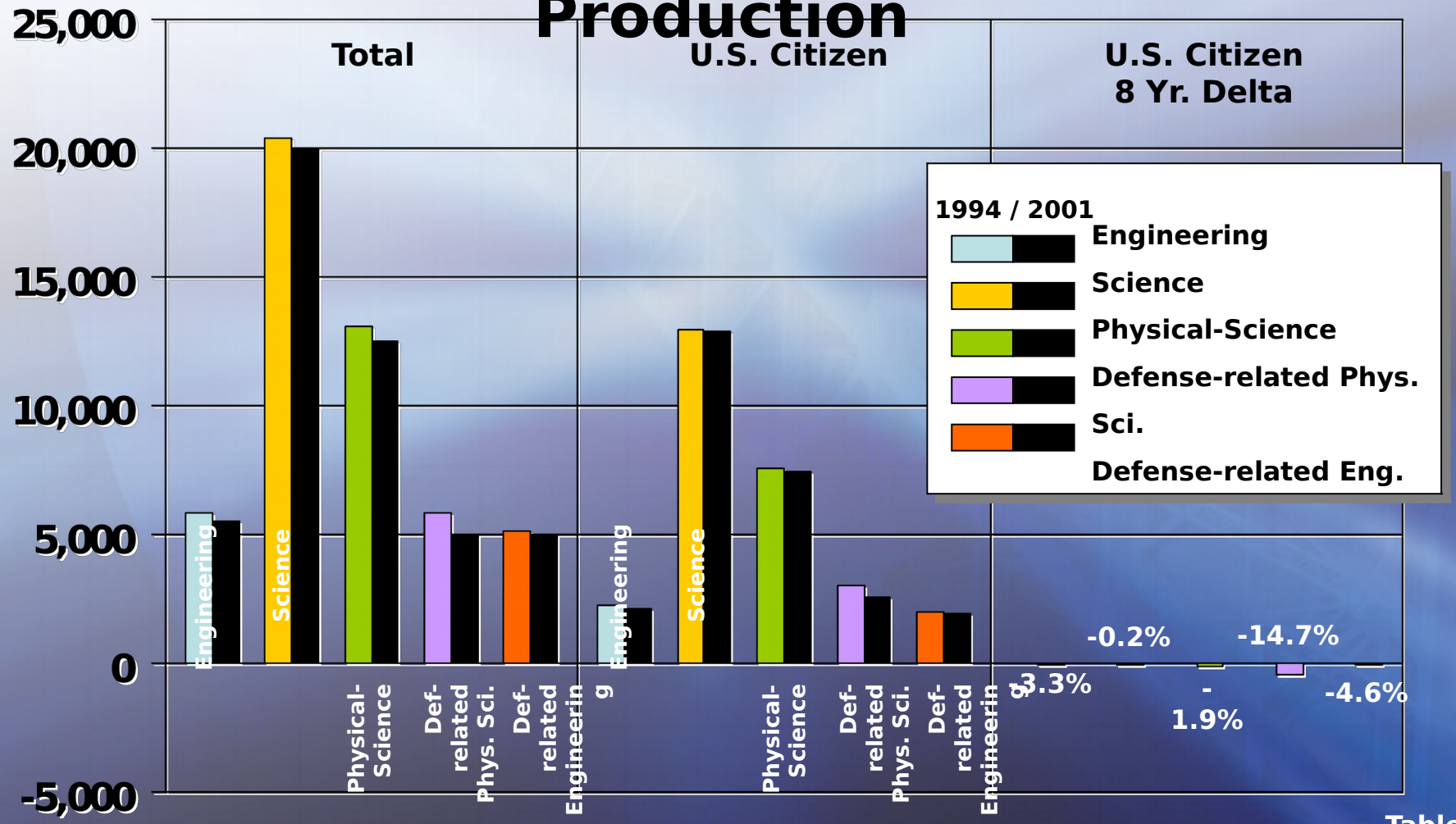


Table IV

Distribution Statement A: Approved for public release: distribution unlimited

U.S. S&E Ph.D. Production Trends (1994-2001)

*Source: National Science Foundation – Science and Engineering Doctorate Awards, 2002

nual U.S. Defense-Related Physical Science Productio

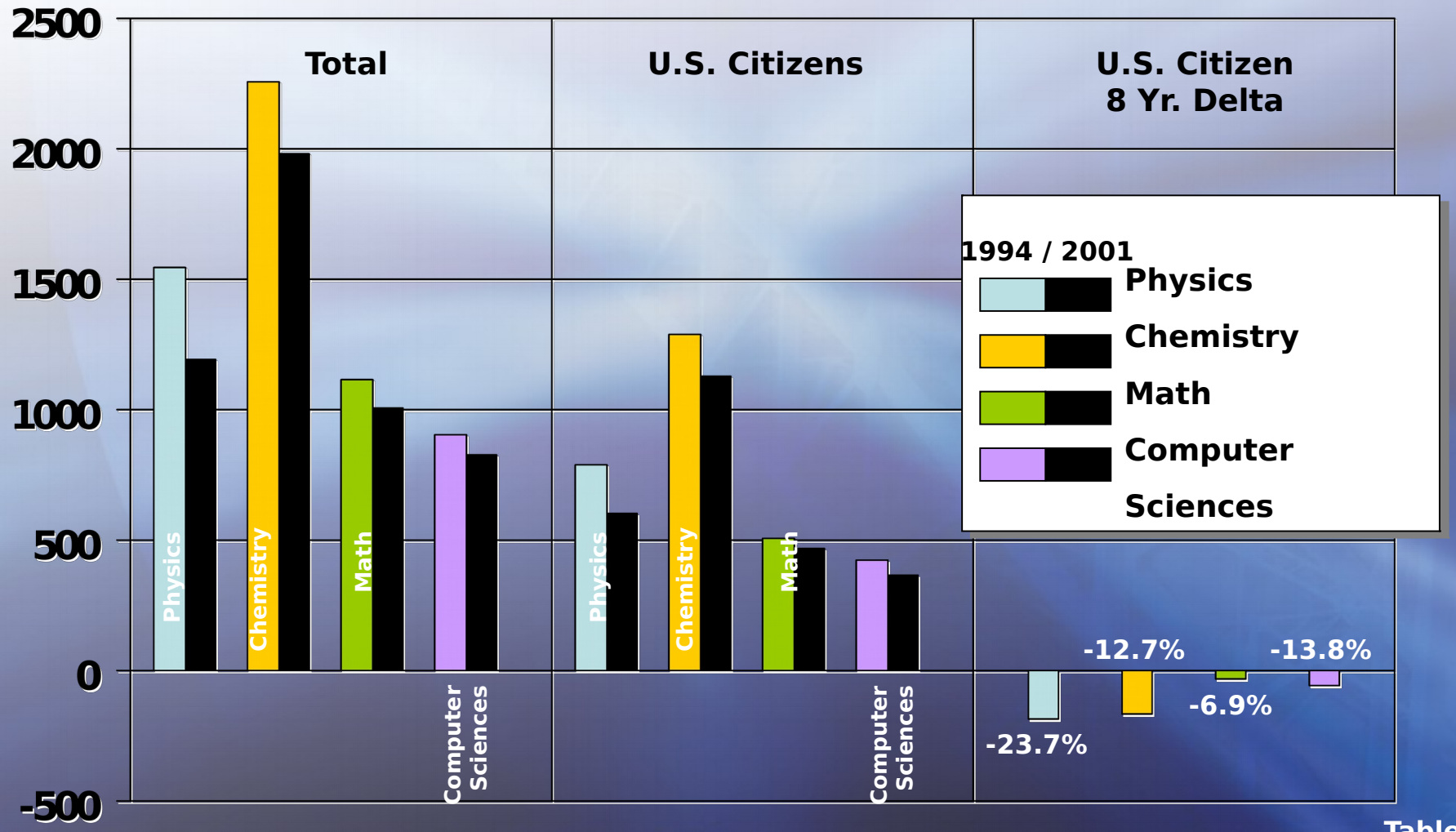


Table V

Distribution Statement A: Approved for public release: distribution unlimited

U.S. S&E Ph.D. Production Trends (1994-2001)

*Source: National Science Foundation – Science and Engineering Doctorate Awards, 2002

U.S. Defense-Related Engineering Disciplines Doctoral Productio

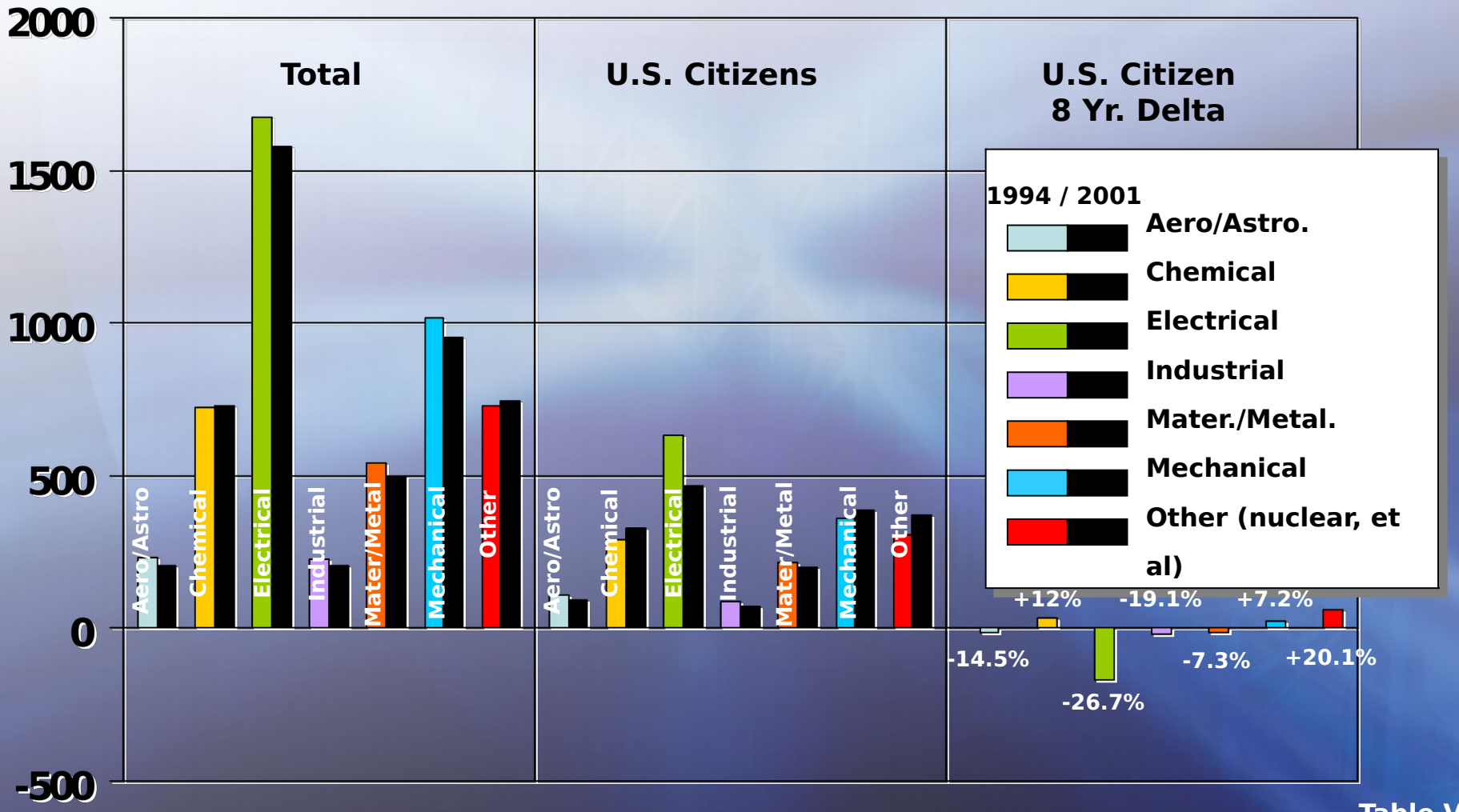


Table VI

Distribution Statement A: Approved for public release: distribution unlimited

Math, Science & Engineering: National Security and the Workforce

No Child Left Behind

Existing DoD Outreach and Education Programs

DoD Education Initiatives

Elementary School Level	Middle School Level	Secondary School Level	Undergrad Level	Graduate Level
• STARBASE • Mentor/Volunteer • Summer Camps • Others	• STARBASE • e-Cybermission • Others	• Materials World Modules (MWM) • Service Progs. • *Modeling & Simulation-Based Math • *Others TBD (BEST) • *DoD Secondary	• Undergrad Research • Freshman Science Experience • Service Progs. • *Modeling & Simulation-Based Math	• National Defense Science and Engineering Graduate Fellowships • Service Progs. • *Graduate Research Traineeships • *DoD Graduate

**Exploring*

Distribution Statement A: Approved for public release: distribution unlimited.

Math, Science & Engineering: National Security and the Workforce

Materials World Module Content

"Integrated" multidisciplinary approach to Physics, Chemistry, Biology, Environmental Science and Geoscience using "materials as a paradigm"

Kindles interest in science and engineering and instills passion for discovery

- Ceramics
- Polymers
- Smart Sensors
- Nanotechnology
- Surfaces and Membranes
- Biodegradable Materials
- Biosensors
- Food Packaging Materials
- Environmental Catalysis
- Metals and Alloys
- Composites
- Concrete
- Sports Materials

- *Modules in use*
- *Modules in test*
- *Modules in design*

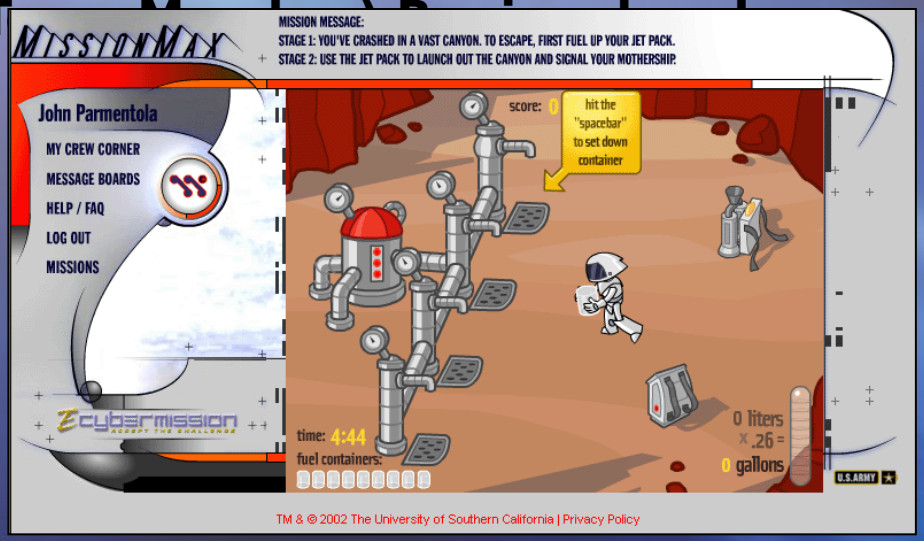
- ***Deployment Based Considerations of MWM Use:***
- ***Adopted by DoD Education Activity in 13 overseas school districts in Fall '00***
- *Adopted in over 500 US schools in 14 states*

Distribution Statement A: Approved for public release: distribution unlimited

eCYBERMISSION

Shows Students that Math, Science and Technology can be interesting and exciting

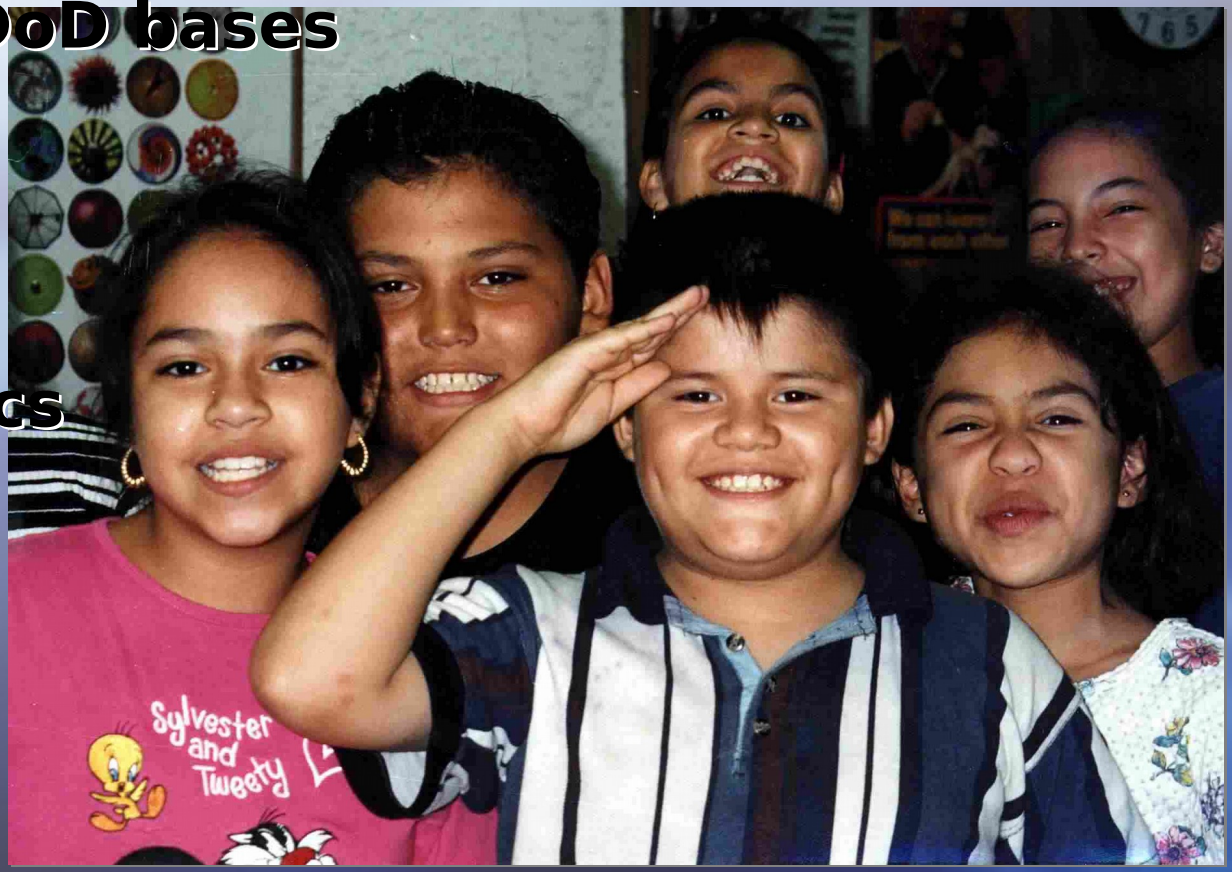
- Supports Army's intent "to give back to the Nation"
  - Attracts an audience of children beyond math/science "stars"
  - Web-based adventure: team competition activities, games, puzzles with solid learning points
- Overview
  - Web Based Competition – Team Effort
  - 6-9th Grade, 3-4 Student Teams + 1 Advisor


MISSION MAX
MISSION MESSAGE:
STAGE 1: YOU'VE CRASHED IN A VAST CANYON. TO ESCAPE, FIRST FUEL UP YOUR JET PACK.
STAGE 2: USE THE JET PACK TO LAUNCH OUT THE CANYON AND SIGNAL YOUR MOTHERSHIP.
John Parmentola
MY CREW CORNER
MESSAGE BOARDS
HELP / FAQ
LOG OUT
MISSIONS
score: 0
hit the "spacebar" to set down container
time: 4:44
fuel containers:
0 liters
x .26 =
0 gallons
U.S.ARMY
TM & © 2002 The University of Southern California | Privacy Policy

Distribution Statement A: Approved for public release: distribution unlimited

STARBASE

- **Primarily At-Risk kids**
- **20 Classroom Hour experience at DoD bases**
- **45+ sites in 28 states**
- **Engaging Science and Mathematics**
- **Grades 5-8**



Distribution Statement A: Approved for public release: distribution unlimited

Summary

- A robust, integrated, capabilities-based research and engineering program provides transformational options
- Cross-Cutting initiatives established:
  - National Aerospace Initiative
  - Energy and Power Technologies
  - Surveillance and Knowledge Systems
- Combating Terrorism Technology Task Force is supporting technical options
- Accelerating the technology transition
- Science & Engineering Workforce: Critical for Transformation

Distribution Statement A: Approved for public release: distribution unlimited

Backup

Distribution Statement A: Approved for public release: distribution unlimited

Army / DARPA Collaboration
Enabling Future Combat Systems

Unmanned Air Vehicles

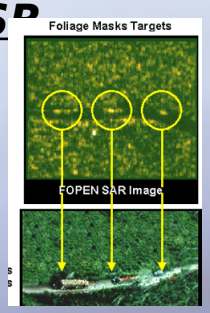
- *Diesel Micro Air Vehicle (d-MAV) ACTD*
- *DP-5X UAV*
- *Organic Air Vehicle*

Autonomy With Intent – UGCV

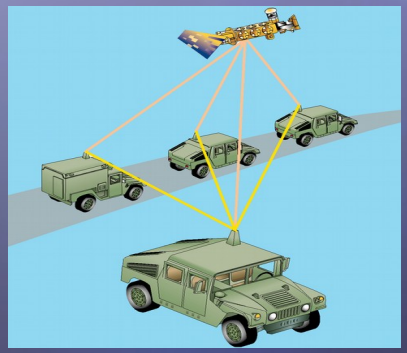
- *Armed Robotic Vehicle*
- *Advanced mobility*
- *Advanced percention*

- *International Cooperation*
- *Studies, Analyses and Experiments*
- *Other*

Find the Enemy – ISR



- *Affordable Adaptive Conformal ESA Radar (AACER)*
- *Foliage Penetrating Reconnaissance, Surveillance and Tracking Engagement Radar (FORESTER)*
- *JIGSAW*
- *Sensor DART*
- *Wolfpack*



Network and Battle Command

- *FCS Communications*
- *Mobile Networked Multiple-Input / Multiple-Output (MNM) Communications*
- *FCS Multi Cell Command and Control (C2)*

Distribution Statement A: Approved for public release: distribution unlimited